[G]EOLOGY OF PARTS OF THE [A]ZUSA AND MOUNT WILSON [Q]UADRANGLES, SAN GABRIEL [M]OUNTAINS, LOS ANGELES COUNTY, CALIFORNIA

SPECIAL REPORT 105

California Division of Mines and Geology
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GEOLOGY OF PARTS OF THE AZUSA AND MOUNT WILSON QUADRANGLES, SAN GABRIEL MOUNTAINS, LOS ANGELES COUNTY, CALIFORNIA

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STATE OF CALIFORNIA
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THE RESOURCES AGENCY
Norman B. Livermore, Jr., Secretary

DEPARTMENT OF CONSERVATION
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ABSTRACT

The mapped area lies in the south-central part of the San Gabriel Mountains and the adjoining part of the Los Angeles basin. Separating these two geomorphic features is the west-striking Sierra Madre fault zone.

A sequence of intercalated pre-Tertiary metamorphic and plutonic rocks, in essentially equal amounts, strikes generally west and underlies most of the mountainous part of the area. Quartz diorite separates a sequence of dominantly cataclastic rocks in the northeast part of the area from a gneiss unit to the south. Orthogneiss, of late Paleozoic age, which crops out in the western part of the area, is separated from the other metamorphic rocks by quartz diorite of Cretaceous age. Andesitic volcanic rocks and clastic sedimentary rocks of Tertiary and inferred Tertiary age occur on the south flank of the mountain front. These rocks are in fault contact with the pre-Tertiary rocks. Volcanic rocks exposed in the eastern part of the area are intercalated with, and in part underlie, beds of the middle-Miocene Topanga Formation. Tertiary hypabyssal dikes ranging from acidic to basic in composition cut the basement rocks.

Isolated patches of the Quaternary San Dimas Formation are all that remain of the Pleistocene alluvial fans originally deposited along the mountain front. Quaternary stream terrace deposits occur in most of the larger canyons.

Landslides and landslide deposits occur throughout the mountainous parts of the area. Many slopes are covered by deposits of unconsolidated colluvial debris. Calculations based upon debris production records for the larger drainage areas indicate degradation rates are extremely high in the area studied.

The dominant structural feature is a frontal fault system termed the Sierra Madre fault, along which the mountains have been uplifted. Reverse movement on this fault zone has deformed the Tertiary sediments into a large overturned syncline, adjacent to the basement rocks. The Clamshell-Sawpit fault zone, a major northeast-striking, northward-dipping feature, emerges from the mountain front at the western part of the area. The latest movement on this zone appears to have been principally dip-slip.

Regional geologic and seismic considerations indicate the fault zones are active. The type of fault movement to be expected is reverse dip-slip. Magnitude of fault displacement should be of the same order as the 1971 San Fernando earthquake with similar ground rupture and attendant geologic phenomena.

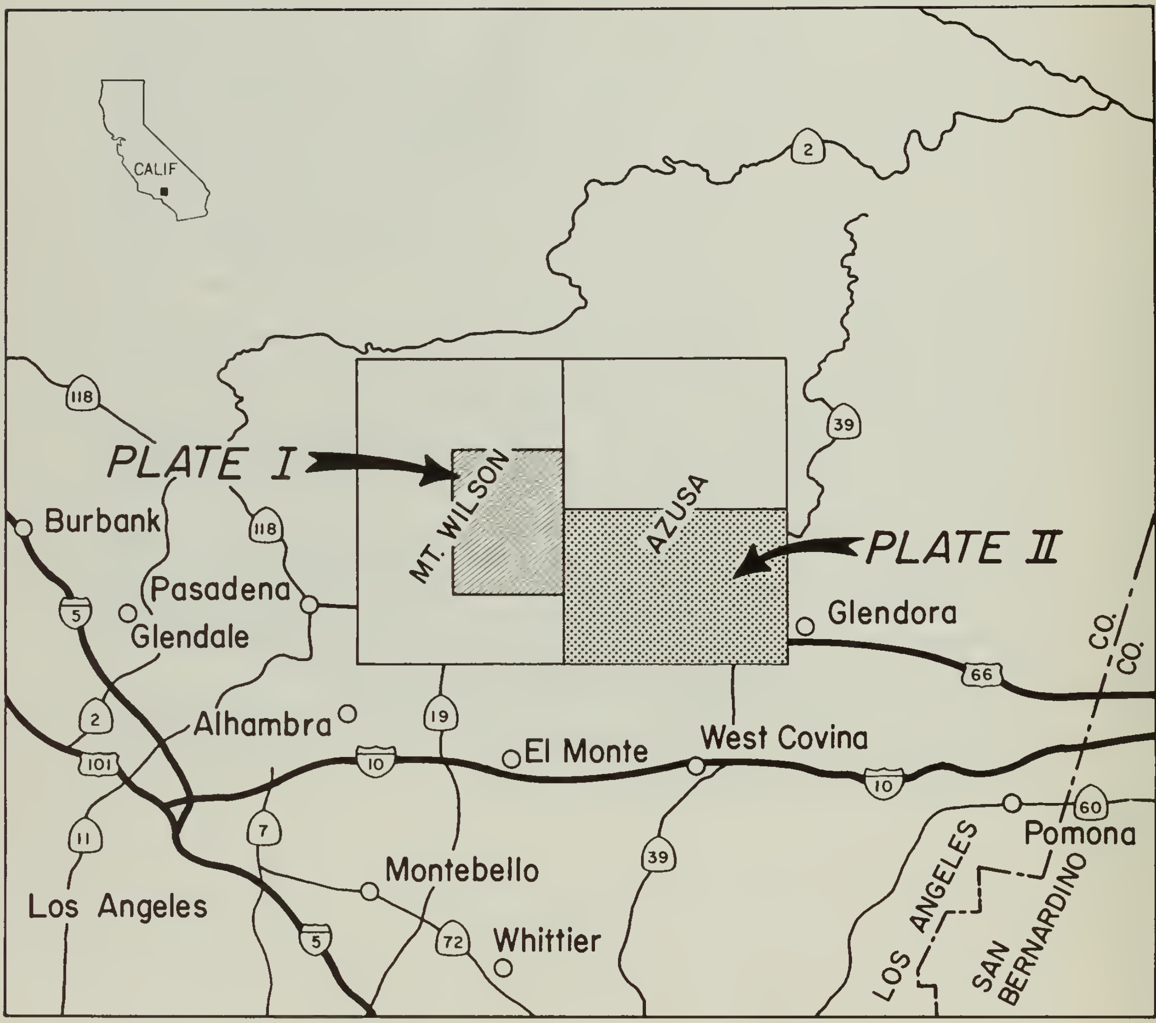

Figure 1. Index map.

GEOLOGY OF PARTS OF THE AZUSA AND MOUNT WILSON QUADRANGLES, SAN GABRIEL MOUNTAINS LOS ANGELES COUNTY, CALIFORNIA

by Douglas M. Morton *

INTRODUCTION

REGIONAL GEOLOGIC SETTING

The San Gabriel Mountains, near the center of the Transverse Range geomorphic province, are a lenticular-shaped range of essentially plutonic and metamorphic rocks. Fault zones bound the range on all sides: the San Andreas on the north, the Soledad on the northwest, the San Gabriel on the southwest, and the Sierra Madre on the south.

PREVIOUS WORK

Prior to 1934, little geologic work was done in this part of the San Gabriel Mountains, although M. L. Hill in 1930, mapping 12 miles west of the area, was apparently the first to show the presence of northward-dipping reverse faults along the mountain front. W. J. Miller, in 1934, published the first map that differentiated basement rocks in the western San Gabriel Mountains. In the same year Rollin Eckis published an investigation of the geology and hydrology of the "South Coastal" basin. Though not differentiating basement rocks, Eckis subdivided the older and younger alluvial deposits along the mountain flanks. Shelton (1955) studied the petrology of Miocene volcanic rocks (Glendora Volcanics) of eastern Los Angeles basin and adjacent areas in the San Gabriel Mountains.

In recent years the United States Forest Service, Pacific Southwest Forest and Range Experiment Station, Glendora, California, has published a series of papers on erosional processes and rates within the San Gabriel Mountains. Dibblee (person communication, 1965) has mapped the entire San Gabriel Mountains. A geologic synopsis of the San Gabriel Mountains, within the framework of the Transverse Range province, is given by Bailey and Jahns (1954).

PRESENT STUDY

This report presents the results of geologic investigation by the Division of Mines and Geology that was partly financed by the County of Los Angeles, Department of County Engineer and the Los Angeles County Flood Control District. The investigation includes the area covered by the south half of the Azusa 7½-minute quadrangle (plate 2), and the east central part of the Mt. Wilson 7½-minute quadrangle (plate 1).

Mapping was done from 1964 to 1967 on U.S. Department of Agricultural aerial photographs, at a scale of 1:12,000. Geologic data were transferred to enlarged (1:12,000) portions of the 1966 editions of the Azusa and Mt. Wilson 7½-minute quadrangles.

LOCATION AND CLIMATE

The area includes the south flank of the San Gabriel Mountains north of the San Gabriel Valley communities of Sierra Madre, Arcadia, Monrovia, Duarte, Bradbury, and Azusa. The San Gabriel Mountains are rugged and steep. Ridge sides commonly have slope angles of 20 to 40 degrees.

The climate of the valley area is semi-arid; the mountains, sub-humid. Average precipitation in the valley area is about 18 inches; in the mountains, 20 to 40 inches. Precipitation occurs mostly in the cooler winter and spring months and usually is intense but irregularly distributed.

ACKNOWLEDGMENTS

The Los Angeles County Flood Control District kindly supplied unpublished debris production data for parts of the San Gabriel Mountains. The Geology Department, Seaver Laboratory, Pomona College, graciously made available space and facilities during the course of this study. The author appreciates discussions on the geology with George B. Cleveland, Clifton H. Gray, Jr., H. A. Kues, Richard J. Proctor, Robert Streitz, A. O. Woodford, and E. J. Zielbauer.

GEOLOGY

The area is underlain mainly by nearly equal amounts of pre-Tertiary metamorphic and plutonic rocks. The spatial arrangement, on a large scale, is that of a generally west-striking sequence of intercalated metamorphic and plutonic rocks. Tertiary sedimentary and volcanic rocks and younger sediments occur along the south flank of the metamorphic and plutonic rocks. The Tertiary sedimentary rocks are in fault contract with the older rocks. The faults located along the front of the range, collectively here termed the Sierra Madre fault zone, generally dip northward. The Clamshell-Sawpit fault zone, consisting of anastamosing faults, extends east-northeast from the mountain front near the mouth of Santa Anita Canyon across the area parallel to Clamshell and Sawpit Canyons, for which it is named. The faults of this

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zone dip northward at moderate angles. Small unnamed faults occur elsewhere in the range.

CRETACEOUS OR OLDER METAMORPHIC ROCKS

A sequence of dominantly cataclastic metamorphic rocks (m_1, m_2, and m_3 units on map) occurs in the northeast part of the mapped area. The southern contact of this northward-dipping sequence strikes west-northwest. Although this sequence is dominantly cataclastic, the northeasternmost unit is mostly unsheared hornblende and biotite-hornblende gneiss (m_1a), which is homogeneous in texture and mineralogy. The principal minerals are hornblende, biotite, plagioclase of intermediate composition, quartz, minor potassium feldspar, and magnetite. Most of the gneiss is dark gray to black, fine to medium grained, with well-developed s-surfaces. The s-surfaces, which are regular in orientation, are at a moderate angle with the strike of the contact between this map unit and the map unit to the south (m_1b). Typically the rock weathers to form rounded dark-colored slopes. The mapped area of the m_1a unit is only a small part of a large complex of this rock that extends northwest, north, and southeast.

South of the hornblende gneiss mass (m_1a), the dominantly cataclastic rock is subdivided into several map units. These, from north to south, include a unit of heterogeneous mixture of deformed granitic rock and cataclastic chloritic gneiss (m_1b) and a series of alternating tabular masses of layered biotite gneiss (m_1c), massive-appearing chloritic cataclasite (m_1d), layered biotite gneiss (m_1c), massive-appearing chloritic cataclasite (m_1d), and a heterogeneous unit of layered gneiss and gneissic granitic rock (m_1e) with local occurrences of a separately mappable gneissic quartz monzonitic rock (m_1f). The northernmost unit (m_1b) is a heterogeneous mixture of chloritized and, in part, cataclastic and gneissic granitic rock of quartz diorite composition intimately mixed with cataclastic chloritic gneiss. The cataclastic gneiss is mostly dark green and fine grained and contains lenses of leucocratic augen gneiss. Dark-green gneiss consists of partly altered biotite and plagioclase, some white mica, and elongate strained quartz grains. Leucocratic augen gneiss lenses are composed of eyes of pink potassium feldspar in a "groundmass" of sheared biotite, altered plagioclase, and quartz. Epidote is a common accessory mineral. Layered biotite-rich and biotite-poor gneiss occurs locally within this unit.

Two layered biotite gneiss units (m_1c) are similar and are discussed together. They consist of alternating discontinuous dark brown biotite-rich and light colored quartz-feldspar-rich layers and lenses. The layers are generally about an inch thick. Most of the rock has been sheared, producing an imbricate structure of gneiss lenses with common local small microscopic tight flow-type folds. This shearing was non-penetrative in contrast to the deformation which produced the cataclastic texture. In general, however, the two planar structures are parallel or subparallel.

The massive-appearing cataclasite (m_1d) is dark green where fresh and brown where weathered. Most of this rock contains chlorite, altered plagioclase and potassium feldspar, and elongate masses of strained quartz. Small amounts of biotite, hornblende, white mica, and a carbonate, in part iron-bearing, also occur. Small thin carbonate veinlets, mostly brown-weathering, cut all other minerals; and epidote commonly coats fractures.

In the northern map unit (m_1d) are some masses of poorly layered biotite gneiss and augen gneiss with small pods, or eyes, of quartz-feldspar 1 to 2 inches long, in an even-grained biotite-quartz feldspar groundmass. Some of this northern unit appears to be an orthogneiss, originally a mafic-rich granitic rock.

The southern and more massive-appearing (m_1d) cataclasite is in general more intensely sheared and resistant to erosion than the northern (m_1b) unit. It also contains a greater amount of iron-bearing carbonate veinlets, which impart a brown coloration to the initially dark green rock.

In the cataclasite are thin zones of mylonite, which is of extremely small grain size, though generally lacks the typical flowage-like texture. Some leucocratic micro-porphyroblastic cataclasite occurs as lens-like masses within the more massive cataclasite.

The southern unit (m_1e) of this sequence is a heterogeneous mixture of sheared gneiss and layered gneiss and gneissic granodioritic-quartz monzonitic rock, with common-to-abundant leucocratic granitic dikes. The unsheared layered gneiss consists of 1- to 3-inch alternating leucocratic quartz-feldspar and dark brown biotite-rich layers. Garnet occurs in the biotite-rich layers in addition to the more abundant biotite, plagioclase, and quartz.

In the area of Roberts Canyon and to the northwest in the northern part of this mixed unit (m_1e) is a separately mappable unit composed of gneissic rock of granodioritic to quartz monzonitic composition (m_1f). It is lighter in color than the quartz diorite rock of unit m_1e and also generally weathers to give lighter gray debris. Most of this rock is medium grained with weak gneissic to locally cataclastic texture.

Between the mouths of San Gabriel Canyon and Santa Anita Canyon is a second strip of metamorphic rock (m_2) bounded on the north and south by quartz diorite rock. The outcrop width decreases eastward and probably pinches out beneath the alluvium at the mouth of San Gabriel Canyon. The westernmost exposure, just west of Santa Anita Canyon, is in fault contact with the quartz diorite rock.

Southeast of the Clamshell-Sawpit fault zone, the trend of this strip of metamorphic rocks is west-northwest, and most of the northern and southern contacts between the metamorphic and quartz diorite rock appear to be intrusive; only locally are there fault contacts. In and northwest of the fault zone the trend is east-northeast parallel to the fault zone. Most of the metamorphic-quartz diorite contacts in this area are fault contacts, though north of Clamshell Canyon the northern contact appears to be intrusive.

East of the Clamshell-Sawpit fault zone, the southern contact between metamorphic and quartz diorite rock dips steeply northward and flattens to moderate angles eastward at Fish and Van Tassel Canyons. The northern contact is generally steep and somewhat irregular though the apparent intrusive contact north of Clamshell Canyon dips at a moderate angle to the north about parallel to the dip of the fault.

South of the metamorphic rocks and east of the Clamshell-Sawpit fault zone, the quartz diorite contains inclusions of metamorphic rocks for distances of a few hundred to more than two thousand feet south of the metamorphic rock. The inclusions are generally small (less than a few feet) though some attain a length of several hundred feet; the largest inclusions are shown on the geologic map.

Most of the rock unit (m_2) is gneiss composed of the assemblages biotite-quartz-feldspar, biotite-hornblende-quartz-feldspar, and hornblende-quartz-feldspar. Less common are marble and calc-silicate rock, and still less common are amphibolite and quartzite. The gneiss is foliated, commonly layered and less commonly massive except where it grades into quartzite, marble, or amphibolite. In texture, it ranges from granoblastic to lepidoblastic with lepidoblastic being the most common. Marble and quartzite have a granoblastic texture; quartz-feldspar rock commonly is augen-textured, while cataclastic textured rock occurs locally.

The gneiss weathers to brown; the marble and quartz weather to off-white. The marble, calc-silicate rock, and quartzite are the most erosion-resistant rocks of this unit.

Biotite and/or hornblende, intermediate composition plagioclase, and quartz are common to abundant. Potassium feldspar is less common. Porphyroblastic crystals of garnet occur in some gneiss and some are mantled by chlorite.

Epidote and chlorite are widespread secondary minerals. They are especially abundant in the vicinity of major fault zones, such as at the mouth of Santa Anita Canyon. Local carbonate-bearing altered rock occurs adjacent to mesocratic hypabyssal dikes.

Though in general not common, marble and calc-silicate rocks are relatively abundant in the area of Fish and Van Tassel Canyons, sparse from Van Tassel Canyon to Sawpit Canyon, and rare west of Sawpit Canyon. Marble is composed of calcite with minor amounts of forsterite partly altered to serpentine, diopsidic pyroxene, apatite, sphene, and plagioclase. The calc-silicate rock is composed of pyroxene, epidote, garnet, carbonate minerals, and quartz.

Gneiss that contains abundant leucocratic granitic rock is differentiated (m_2a) in the Monrovia Canyon area. Between and south of the mouths of Monrovia and Santa Anita Canyons, several lenticular masses of gneissic rock similar to the gneiss (m_2) to the north are included with it.

Small bodies of gneiss (m_3) occur along the mountain front from west of Santa Anita Canyon to the west boundary of the area. The southwesternmost body appears to be the eastern end of a body that increases in size to the west beyond the limits of the map.

Between Santa Anita and Little Santa Anita Canyons, the gneiss, very poorly and discontinuously exposed, is biotite gneiss and/or hornblende gneiss, with considerable amounts of gneissic leucocratic granitic rock. In places, these bodies are in fault contact with quartz diorite to the north.

Just west of Little Santa Anita Canyon are several exposures of relatively light colored biotite gneiss. Where seen, the gneiss is in fault contact with quartz diorite to the north.

The rocks at the west edge of the mapped area are biotite, biotite-hornblende, and hornblende gneiss layered with some relatively light-colored biotite granitic gneiss and biotite gneiss with augens of feldspar.

Lineations and minor folds are locally common (for example, Van Tassel Canyon) within the gneiss (m_2). The lineation is generally due to oriented hornblende prisms or streaks of quartz-feldspar on s-surfaces. Thin calc-silicate layers in marble generally have been folded into complex flow-type folds.

Upper Paleozoic Metamorphic Rock

A third major band of metamorphic rock (m_{4a}, m_{4b}) is in the northwest corner of the mapped area. It is in contact with granitic rock to the north and south, extends east and west beyond the bounds of the area, and is unlike other metamorphic rocks in the area. The southern unit (m_{4a}) is a very distinctive, relatively uniform, light colored orthogneiss containing striking porphyroblasts (relic phenocrysts) of hornblende and, less commonly, potassium feldspar. This is the "hornblendic foliated facies" of the Mount Lowe Granodiorite of Miller (1934, p. 42–43) and is an extension, or fragment, of a large granitic complex extensively exposed north and east of the area. It currently is being investigated by Ehlig (1966) and Silver (1966). Silver has determined the age of the Mount Lowe igneous complex to be 245 ($\pm$ 10) million years by use of the Pb^{200}/U^{238} ratio.

North of this orthogneiss is a heterogeneous assemblage (m_{4b}) of orthogneiss, gneiss with hornblende and/or biotite only in very small amounts, and gneissic grantic rock of quartz diorite or granodioritic composition. These latter rocks are unlike Miller's typical Mount Lowe Granodiorite and are probably related to adjacent Cretaceous age plutonic rocks. The mixed (m_{4b}) unit grades northward into massive quartz diorite.

The contact between units m_{4a} and m_{4b} is arbitrarily placed where the gneissic rocks become relatively homogeneous to the south. This is a transitional zone as much as several hundred feet wide.

The contact between the southern homogeneous unit (m_{4a}) and the quartz diorite to the south is clearly intrusive. A zone of quartz diorite with abundant inclusions of orthogneiss forms, in places, a separate mappable zone. Inclusions of distinctive hornblende orthogneiss rock were found in the quartz diorite more than 4,000 feet south of the contact.

West of Santa Anita Canyon, the gneiss (m_{4a}) is relatively uniform in width with a generally steep dip to the north. To the east, between Santa Anita Canyon and Upper Clamshell Road, the gneiss has been progressively assimilated by quartz diorite. At Upper Clamshell Road, the gneiss is completely incorporated in quartz diorite, resulting in a wide zone of massive quartz diorite with common-to-abundant inclusions of hornblende gneiss. Some of these inclusions attain a length exceeding several tens of feet. Dikes and small bodies of pegmatite granite and finer grained granite are common in the gneiss.

The hornblende-bearing gneiss is a coarse-grained mottled gray rock with porphyroblasts (relic phenocrysts), about ¼–½ inch long interspersed with less common porphyroblasts (relic phenocrysts) of potassium feldspar with finer grained plagioclase of intermediate composition, potassium feldspar, quartz, and fine-grained hornblende and biotite. Hornblende crystals generally comprise from 5 to 7 percent of the rock and are commonly altered to chlorite.

Plagioclase, averaging about 30 percent in the rocks examined, occurs as anhedral equant-shaped grains, .5 to .75 mm long. Most rocks appear to have more plagioclase than potassium feldspar. Potassium feldspar occurs as relic phenocrysts and small equant crystals of the same dimension as the plagioclase.

MESOZOIC PLUTONIC ROCKS

Plutonic granitic rocks (qd unit on map), predominantly quartz diorite, comprise about half of the exposed bedrock in the area. These rocks range in composition from diorite to granite, the latter being confined to small bodies and dikes. The age of quartz diorite from the crest of Mount Wilson, a short distance north of the area, was determined to be 122 million years (Pb/Zircon) (Larsen *et al.*, 1958, p. 48), indicating the granitic rocks to be part of the Mesozoic batholithic complex of California. It is assumed the minor granitic rock bodies and pegmatite dikes are of similar age.

Quartz Diorite

Plutonic rock of mainly quartz dioritic composition, but grading into granodiorite, less commonly quartz monzonite, and locally dioritic compositions, comprise several large west-trending bodies intercalated between metamorphic rocks; this granitic rock was termed Wilson Diorite by Miller (1934). It is generally gray and gray-to-brown-weathering. Texturally it is medium grained, hypautomorphic and xenomorphic-granular to gneissose, and rarely cataclastic. Locally dark-colored ellipsoidal inclusions are common; schlieren are rare. In all but the northwest corner of the area, this rock unit is incipiently to thoroughly fractured and altered, with alteration especially pronounced east of the Clamshell-Sawpit fault zone. Epidote is a widespread mineral in the altered rocks, occurring as coating on, or filling, fractures; it is especially pronounced in the quartz diorite rock just

Photo 1. Quartz diorite (qd) cut by numerous granitic pegmatite dikes, Chantry Flats area, Santa Anita Canyan.

north of the northernmost fault of the Clamshell-Sawpit fault zone.

Carbonate veinlets, generally weathered brown, commonly occur in rock adjacent to intermediate and basic composition hypabyssal dikes. Quartz veinlets are locally common to abundant on the south side of Glendora Ridge, north of Azusa. Light green fluorite occurs in a few of these veinlets.

Throughout most of the quartz diorite are common fine-grained leucocractic, intensely fractured granitic dikes. West of the Clamshell-Sawpit fault zone, numerous granitic pegmatite dikes cut the quartz diorite. These dikes, most abundant from beyond half a mile north of the mountain front, characteristically contain large pink potassium feldspar crystals.

Along intrusive contacts with metamorphic rocks, inclusions of recognizable parentage are common to abundant; some inclusions reach a length of several hundred feet. Rock containing consistently abundant inclusions has been indicated on the map (for example, north of Duarte and on the east side of Santa Anita Canyon).

Along Glendora Ridge, inclusions of gneiss, which range from a few inches to masses large enough to be mapped, are common. Quartz diorite in the vicinity of these inclusions appears to be enriched in potassium feldspar.

East of Monrovia Canyon, for approximately 2 miles, the granitic rock (qd_1) is a mixture of massive to foliated quartz diorite rock, granodioritic-to-granitic rock (commonly gneissic or cataclastic), and light-colored quartzo-feldspathic gneiss. Seen from a distance, this assemblage appears as brown slopes quite distinct from grayer slopes underlain by more homogeneous quartz diorite rock. This rock (qd_1) is well to intensely fractured, locally sheared, generally altered, and deeply weathered. The contact between this rock and the more homogeneous rock to the north is sharp and readily visible in Monrovia Canyon but becomes indistinct to the east. The apparent stability of this rock (no major landslides) is probably due, not to any physical property, but to low relief.

The most homogeneous and freshest quartz diorite occurs in the northwest corner of the area, north of the gneissic rocks (M_4). It differs from other quartz diorite in the area in that it is generally finer grained, more homogeneous, and only slightly altered. It is also more resistant to erosion than other granitic rocks; the upper reaches of Santa Anita Canyon (Winters Creek) and Little Santa Anita Canyon, south of the outcrop area of this unit, abound with resistant boulders of this rock.

Mineralogically, most of the rock is either biotite-hornblende or hornblende-biotite quartz diorite and less common granodiorite. Hornblende occurs as tabular to irregular crystals, 2–4 mm long. It is commonly partly to thoroughly altered to calcite, epidote, and chlorite. Biotite, of the same dimensions as the hornblende, occurs as subhedral plates that are commonly altered in part or totally to chlorite. Intermediate-composition plagioclase, also commonly altered, occurs as equant to tabular crystals as much as 5 mm long. Quartz occurs as strained anhedral masses of the same dimension as the plagioclase.

Potassium feldspar, generally in interstitial disposition, occurs in some quartz diorite in amounts up to several percent; it is, of course, present in larger amounts in the more acidic rock. Epidote occurs in some rock as widespread small crystals.

Minor Granitic Rock Bodies and Pegmatite Dikes

Granitic rock (g unit on map) occurs as dikes and small plutons, which cut quartz diorite and metamorphic rocks. The rock is generally leucocratic (white, buff, to pale yellowish), medium to fine grained, and massive to gneissic. Included is some dike rock of complex granitoid and pegmatoid texture. Generally the rock is strongly fractured; rocks on the south side of Glendora Ridge are commonly veined with quartz and, very locally, with fluorite.

Light-colored pegmatite dikes, of granitic composition, occur mostly in quartz diorite and mainly in the western part of the area (Mt. Wilson quadrangle). These dikes are sparse along the mountain front but become common to abundant beyond about half a mile north. They range in width from a few inches to several feet and are generally discontinuous in length, as well as irregular along strike and branching. The pegmatite rock is characterized by large pink potassium feldspar crystals. Besides potassium feldspar, the pegmatite rock is composed of quartz and sodic plagioclase with smaller amounts of biotite, muscovite, zircon, and columbite.

TERTIARY ROCKS

Volcanic and sedimentary rocks of Tertiary and inferred Tertiary age are exposed discontinuously along the mountain front. They are most abundant north of Azusa, less abundant between Duarte and Monrovia, and occur in a small exposure between Monrovia and Santa Anita Canyons. Dikes of Tertiary, and assumed Tertiary age exist within the mountains.

Glendora Volcanics

Volcanic rocks (Tg, Tgf, Tgb, Tgi units on map) are discontinuously exposed north of Azusa. These rocks in part are intercalated with the middle Miocene Topanga Formation; in part underlie the stratigraphically lowest exposed portions of the Topanga Formation; and in part intrude basement rocks.

Shelton (1946) gave the name Glendora Volcanics to those volcanic rocks "exposed in the foothills of the San Gabriel Mountains in the vicinity of Glendora, in the South Hills, and at the northeast end of the San Jose Hills." The rocks north of Azusa are the northwesternmost occurrence of the Glendora Volcanics as defined by Shelton.

The volcanic rocks in the area consist of flows, breccias, and shallow intrusives locally containing fracture-filling white silica seams. They are poorly exposed and support a cactus-dominated vegetation, which, in general, is an indication of their presence.

Most of the volcanic rocks appear to be of andesitic composition. They are generally fine grained porphyritic, gray, maroon, or reddish brown and partly decomposed. Phenocrysts are mostly plagioclase and altered hypersthene(?). Locally these rocks contain a crude sheet-like planar structure that is suggestive of flow structures oriented nearly parallel to the contact with the Topanga Formation.

Black vesicular basalt (Tgb) occurs interbedded with Topanga sedimentary rock north of the Rainbow Club. Some vesicles are filled or partly filled with silica or carbonate or both.

Also intercalated with Topanga Formation rocks is a fine-grained dense olivine basalt just north of Sierra Madre Avenue. Its lack of vesicles suggests it is probably a sill. Shelton (1955, p. 68–69, u. 72) gives a mode and chemical analysis for this rock (his sample S-422).

Hypabyssal andesitic intrusives (Tgi), which are similar to the extrusive volcanic rock but with a slight increase in grain size, occur as dikes in the granitic rock.

Leucocratic Hypabyssal Dikes

Hypabyssal acidic dikes (Td_2 unit on map) occur throughout the area but are more common in the Azusa than the Mt. Wilson quadrangle and are probably related to the Miocene volcanic activity. The dikes, off-white in color, range in width from a foot to several tens of feet and reach lengths of up to several hundred feet. In texture they range from felsitic to porphyritic with phenocrysts of quartz, feldspar, and biotite. Some of the dikes show pronounced flow banding. The groundmass is composed of extremely fine-grained feldspar, which is commonly altered, quartz, carbonate, and unidentified secondary minerals. Quartz phenocrysts are generally embayed rough bipyramids as long as an inch. Feldspar phenocrysts, altered to carbonate and white mica, range in size from about .005 to .04 inch. Euhedral to subhedral biotite of similar size is generally altered or partly altered to chlorite.

The biotite-bearing rocks appear to be similar to the Mountain Meadows Dacite of Shelton (1955, p. 54). A biotite-rhyodacite, possibly related to the Mountain Meadows Dacite, from Mystic Canyon, Glendora quadrangle, gave a K-Ar age of 27.5 $\pm$ 2.5 million years (Robert Streitz, personal communication, 1965).

Intermediate to Basic Hypabyssal Dikes

Dike rock (Td_1 unit on map) not physically resembling the Glendora Volcanics occurs throughout most of the area of exposed basement. These dark-colored dikes range from one to several tens of feet in width and up to several hundred feet in length. Some singular appearing dikes consist of closely spaced en echelon parallel dikes.

Over much of the area, there appears to be little, if any, systematic disposition of these dikes. An exception are basaltic dikes in the Mt. Wilson quadrangle where most dikes are oriented with a northern strike. Both types of dike rock are distributed over the area, but the basaltic dikes are much more abundant in the quartz diorite in the Mt. Wilson quadrangle and are less abundant to the east.

In composition, the dikes can be divided into andesitic, which are generally brown and relatively fresh, and basaltic, which are deep brown and deeply weathered. Texturally the basaltic dike rock is even grained; the andesite is subporphyritic to porphyritic. Some andesitic dikes contain flow structure, and a few basic andesitic or basaltic dikes have vesicular margins. The vesicles are partly filled by carbonate minerals; carbonate is also common adjacent to many dikes. Dikes of andesitic composition are composed of fine-grained intermediate composition plagioclase, hornblende, augite, and opaque minerals with phenocrysts of plagioclase, hornblende, and less commonly magnetite. Most of the phenocrysts are embayed. Some phenocrysts of hornblende are mantled with reaction rims of opaque minerals, chlorite, and feldspar. Some rock contains carbonate minerals from minute quantities to several percent. Most of these minerals are clearly of secondary origin, but some appear to be a primary mineral.

Basaltic dikes, many showing spheroidal weathering, are essentially fine grained with commonly aphanitic chilled margins. The fresher rock is composed of subhedral to euhedral plagioclase (laboradorite) laths and subhedral to interstitial augite in an extremely fine-grained matrix of chlorite, greenish biotite(?), and secondary minerals. Some aggregates of talc(?) and iddingsite(?) appear to be pseudomorphous after olivine.

Topanga Formation

Rocks correlated with the Topanga Formation (Tt unit on map) (middle Miocene) are exposed north of Azusa. Shelton (1955, p. 71–76) states Luisian foraminifera were reported from these rocks and "the highest beds exposed yielded fish scales that are probably either uppermost Luisian or lowermost Mohnian." Glendora Volcanics are intercalated with these sediments. Most of the Topanga Formation is coarse-grained, massive, thick-bedded sandstone; conglomerate; fine-grained, thinly bedded sandstone; siltstone; and some diatomaceous, fissile, and partly silicified shale. The silty, sandy, and conglomeratic materials are buff and yellowish; the shales, off-white and grayish.

Conglomerate clasts, a few as much as several feet in diameter, are predominantly granitic and gneissic, resembling rocks from the San Gabriel Mountains. Subordinate volcanic clasts resembling rocks of the Glendora Volcanics are also present.

Some sandstone beds are graded; others are cross-bedded. Cross-bedding in the northernmost outcrops indicates the beds are overturned; farther to the south, they appear to be right side up. The overturned beds dip northward into the mountains, the normal beds southward, with vertical beds in between.

Sedimentary rock of lithology similar to the Topanga beds of the Luisian stage north of Azusa crop out north of Bradbury. This rock is here tentatively correlated, on the basis of lithology, with the Topanga Formation. No fossils were found during this study, and Shelton (1955, p. 76) states these rocks "have yielded no diagnostic fossils." Lithologic differences between the Bradbury and the Azusa area rock are lack of shale and intercalated volcanic rock in the former. Locally, the Bradbury rock contains a monolithologic conglomerate composed of gneissose quartz diorite. A few light brown-buff, silty to fine-grained sandstone beds occur in the conglomerate. This type of conglomerate is well exposed at the east abutment of the Los Angeles County Flood Control dam at the confluence of Spinks and Bradbury Canyons.

Duarte Conglomerate

Unconsolidated conglomerate crops out in several places along the mountain front between Maddock and Monrovia Canyons. Shelton (1946) proposed the name Duarte Conglomerate for this rock unit (Tdc unit on map).

This conglomerate is relatively massive with poor bedding and some local sandy beds and lenses. Gray and unconsolidated, it is readily differentiated from conglomerate of the Topanga Formation. Clasts, generally well rounded and several feet in diameter, are mostly of granitic and gneissic rocks similar to those of the San Gabriel Mountains and thoroughly decomposed volcanic rocks similar to the Glendora Volcanics. There are local adobelike, clay-rich beds.

West of Bradbury Canyon, the beds dip steeply north and south; the north-dipping beds are probably overturned though no unambiguous geopetal structures were found. Shelton (1955, p. 77) found, however, that "occasional beds of sand and fine gravel show graded bedding with dips of 50°–80° N. and repeated evidence that these are overturned."

Duarte Conglomerate exposed in a roadcut just east of the mouth of Scott Canyon is cut by a fault with a near west strike and a dip of about 80 degrees south. North of this fault, bedding in the Duarte Conglomerate dips less than 20 degrees to the south and strikes approximately west. To the south, the bedding appears also to strike about east-west but dips 80 degrees to the south. The conglomerate, north of the fault, is either conformably or disconformably overlain by the San Dimas Formation.

No fossils have been found in the Duarte Conglomerate. It is probably a fanglomerate formed at the base of the San Gabriel Mountains prior to deposition of the San Dimas Formation. Shelton (1955, p. 77) thought it to be "probably a fanglomerate and may be the subareal equivalent of part of the thick marine Pliocene sections exposed 11 miles southwest." He said it was also remotely possible that the Duarte bears this kind of relationship to the late Miocene, rather than to the Pliocene.

QUATERNARY DEPOSITS

San Dimas Formation

Along the base of the mountain front are widespread occurrences of dissected older alluvial fan(?) deposits (Qsd unit on map). These clay-bearing deposits are generally readily discernible from younger alluvial deposits by their red-brown color. The name San Dimas Formation was given by Eckis (1928, p. 235) to similar alluvium in the Cucamonga district about 5 miles east. At the "type locality" in San Dimas, portions of a *Elephas imperator*(?) skeleton of Pleisocene age were found (Eckis, 1928, p. 235).

The San Dimas Formation consists generally of gravel, sand, silt, and clay which is massive to poorly bedded, poorly consolidated, and moderately to slightly decomposed. Small fresh aplite and leucogranitic clast alignments define crude bedding. Clasts of other rock types are generally decomposed. Most of the formation is relatively clay rich and locally very clay rich, massive-appearing, well-indurated, adobe like alluvium. This material is locally relatively expansive.

In many places, the dip of this unit is not greater than a few degrees and is therefore considered to be relatively tectonically undisturbed. Locally, dips are as much as 50 degrees, indicating post-depositional deformation. This is especially noticeable in the areas underlain by Duarte Conglomerate and Topanga Formation. Near the mouth of Spinks Canyon, the San Dimas Formation appears to overlie Duarte Conglomerate conformably. Elsewhere, such as near the mouth of Bradbury Canyon, an angular unconformity exists between the two. Farther to the west, the Duarte appears to be in fault contact with the San Dimas. These features indicate local deformation after deposition of the Duarte Conglomerate and during and after deposition of the San Dimas Formation.

Alluvial Deposits in the San Gabriel Mountains

Older stream terrace deposits (Qao unit on map) occur perched above stream beds, at the mouths of some of the larger drainages, and less commonly on ridge tops. They are unconsolidated, gray to brown or tan, massive to poorly bedded with boulders and cobbles in a sandy-pebbly matrix. Boulders are rounded, mostly fresh, and locally attain a length of 8 to 10 feet. In part, these deposits are overlain by colluvial debris, slope wash, or at the mouth of some canyons younger alluvium. Sawpit and Monrovia Canyons contain the most extensive array of these older terrace deposits. Less abundant deposits occur in the upper reaches and mouth of Little Santa Anita Canyon and in San Gabriel Canyon.

Older alluvium (Qao_2 unit on map) of undetermined age occurs perched along some of the larger drainages, especially San Gabriel Canyon, and, in several isolated cases, along ridge tops. This alluvium, like the San Dimas Formation, is generally brownish; however, it occurs at several different elevations and is undoubtedly of slightly different age. In part it may be related (correlated) to the San Dimas Formation (Qsd). Generally the alluvium is conglomeratic and commonly consists of a lower part composed of stream gravels overlain by debris probably in large part either derived by mass-wasting processes or having been transported only short distances from its source area.

Alluvium (Qal unit on map), generally grayish, occurs along the floors and as low younger stream terrace deposits in some of the larger canyons. These deposits generally consist of fresh coarse sand, pebbles, cobbles, and boulders; the latter reach a length of about 10 feet. The younger stream deposits are differentiated from the older stream terrace deposits generally on the basis of their color and lower elevation above the stream channel. Extensive alluvial deposits (Qal) in canyons, such as Roberts and Fish, are a result of heavy debris production following brush fires and are in the process of being flushed out of the canyon.

Alluvial Deposits in the San Gabriel Valley

Units of valley alluvium (Qal unit on map) not subdivided in the area of the Mt. Wilson quadrangle, which is extensively covered with a variety of structures. In the Azusa quadrangle, the alluvium is divided into seven mappable units (Qal_5, Qal_4, Qal_3, Qal_{3a}, Qal_2, Qal_{2a}, Qal units on map).

The dominant alluvial feature of the valley area in the Azusa quadrangle is the San Gabriel River fan (Qal_2). The San Gabriel River today is confined by a channel from the mouth of San Gabriel Canyon to Santa Fe Dam. The remainder of the fan is not subject to reworking. The unconsolidated material of this fan consists of cobbles and boulders, which attain a maximum dimension of 6 feet, in a gray gravel-and-sand matrix. There appears to be a smaller amount of very large boulders in the river channel than over the adjacent part of the fan. The fan supports sumac-yucca types of vegetation, except for the channel, which supports little vegetation.

East of the San Gabriel River fan, the alluvium (Qal_1) is predominantly brown, fine-to-coarse sand in a matrix of silt and clay. It is commonly gray-brown and locally gray with small to large amounts of small angular rocks along the mountain front. Farther away from the mountains, the material is fine grained and darker brown. The darker brown material, in large part derived from the San Dimas Formation, contains moderate amounts of clay and rarely includes cobbles of basement rock.

West of the San Gabriel fan is light brown sandy alluvium (Qal_3) containing angular to round clasts 1 to 12 inches in diameter. Larger clasts are generally subrounded to rounded; smaller clasts are subangular to angular. Where the Duarte Conglomerate occurs in the source area, rounded cobbles occur in greater amounts. A fan at the mouth of Bradbury Canyon is composed of similar alluvium (Qal_{3a}) but is of slightly lighter color and contains a greater amount of subangular to subrounded granitic clasts.

The fan deposits of Monrovia-Sawpit Canyons occur at the western edge of the Azusa quadrangle. At and near the mountain front, the fan consists of two units: an older fan deposit perched on a yet older stream terrace or fan deposit and a younger fan east of the older fan. The older fan (Qal_4) is composed of unconsolidated light brown sandy alluvium and contains common to abundant cobbles and boulders. Most of the cobbles and boulders are of quartz dioritic composition and reach a maximum size of 8 feet near the mountain front. The younger fan (Qal_5) is composed of a grayish sandy pebble alluvium with cobbles and small boulders near the mountains.

RECENT DEGRADATIONAL PROCESSES AND PRODUCTS

Landslides

The most impressive products of mass-wasting processes are large landslides, which occur throughout the San Gabriel mountains. Less obvious, though involving a much greater volume of material, are widespread occurrences of small landslides and colluvial debris.

Landslides (Qls, Qls_1, Qls_2, Qls_3, Qls_4 units on map) large enough to be shown on the accompanying geologic map are considered to form a series, in terms of movement, with three end members: falls, slides, and flows. Many landslides are of composite origin, or their mode of movement is uncertain (Qls unit on map).

Falls (Qls_4), the least common of the three landslide types, originate primarily by free falling and tumbling of rock masses. Their occurrence is confined to particularly steep canyon walls. Slides are by far the most common landslide type in the area. Slides are divided, where possible, into two movement types: those involving primarily rotational or slump movement (Qls_1 unit on map) and those involving translatory, or planar, movement (Qls_2 and Qls_3 units on map).

Principal evidence of a rotational slide is the presence of a relatively level area, or series of level areas, immediately below the scarp. Rotational movement(s) accounting for the flattened surface(s) often occur or are taken up in the landslide mass and not necessarily on the failure (slip) surface between the landslide and underlying material. Small closed depressions formed on the flattened areas of many such landslides are filled with fine debris and commonly support more grass than adjoining areas.

Planar slides are so designated where the landslide mass appears to have moved more or less as a unit, or series of units, with little if any rotational movement in or between units or at the slip surface. No extensive flattened areas are produced below the scarp. In landslides covering equal area, rotational slides are generally thicker than planar slides.

Flows, which in the mapped area are generally too small to be shown on the geologic map, are landslides which deform and flow like a viscous fluid. Debris is the material involved in flows.

Where possible, the anatomy of individual landslides has been indicated on the geologic map. Most commonly this consists of differentiating the scarp from the landslide deposit. In the case of old or poorly exposed landslides, the scarp and the landslide deposit are mapped as a single unit. The reason for the inclusion of the scarp with the landslide is that the scarp area is mechanically related to the landslide and, more practically, the scarp area is generally over-steepened and the material underlying the scarp is considered likely to fail in the future. Many of the larger landslides appear to have formed by multiple failures. It is likely that, following an initial failure, part of the material underlying the scarp area would fail, buttressing itself against the older failure.

The control governing the distribution of landslides in this part of the San Gabriel Mountains appears to be the degree of fracturing of the rock and slope angle. Lithology has little apparent effect on the distribution of landslides. Any original physical differences in competency have been largely obliterated by the pervasive fracturing of all the rocks. Nearly the entire area appears to be a likely site for the development of landsliding, as most of the basement rocks are well to thoroughly fractured and slopes are moderately to extremely steep. In the northwestern part of the area, the rocks are generally less fractured than elsewhere though slope angles remain steep.

Orientation of the slope face influences the distribution of landslides. North-facing slopes and, to a lesser degree, northeast- and east-facing slopes are more deeply weathered and contain more humic materials than do south- and west-facing slopes. These differences account for the fact that a greater number of small shallow (few inches to a few feet) flow-type landslides have developed on the north-facing slopes. These flows are generally too small to be shown on the geologic map. The failure surface is generally at the contact between in-place rock and the overlying debris or, in grassy areas, at the base of the grass roots. Failure occurs generally when the debris above the bedrock becomes saturated with water.

Talus

Talus (Qta unit on map), the conical accumulations of angular rock fragments, is intimately associated with rockfalls. These deposits, restricted to the base of extremely steep slopes, are the result of innumerable small rockfalls. The slope angle of talus is the angle of repose for the material composing the talus. Talus is sorted with the largest rock fragments farthest from the apex of the cone.

Talus occurs in several small areas along the margins of the San Gabriel floor where slopes have been oversteepened because of rock slides or quarrying.

Colluvial Debris and Slope Wash

Many slopes are partly covered by unconsolidated debris ranging from coarse rock fragments with a small amount of fine debris accumulating on steep slopes to mixtures of about equal amounts of rock and soil on moderate slopes. Deposits of such materials are collectively termed colluvial debris (Qc unit on map). They were mapped where they appeared to be thicker than 2 or 3 feet.

With an increase in the fine fraction and a decrease in the slope angle, colluvial debris grades into slope wash (Qsw unit on map). This transition occurs where sufficient soil has developed, principally along the foot of the mountain front and in a few places along ridge tops. The coarser type of colluvial debris grades into talus.

Colluvial debris that contains the highest percentage of coarse rock fragments is not as common on slopes facing north as on slopes facing other directions. This is due to the less weathered nature and lower humic content of materials on slopes facing south. Other factors being equal, colluvial debris appears to be more common on quartz diorite than on other rock types.

Downslope movement of colluvial debris occurs through creep and sliding. Debris creep is the most widespread type of creep; soil creep is the next in importance; and rock creep is, from the standpoint of area, unimportant. Debris creep is common throughout the area on all degrees of slopes. Soil creep is prevalent on north-facing slopes in relatively soil-rich materials and in materials elsewhere that are transitional to slope wash. Rock creep is limited to a relatively few occurrences in colluvial debris deposits of essentially soil-less areas. Sliding is quantitatively important in the downslope progression of the debris. The areas of individual landslides are small compared to the sizes of the colluvial debris deposits, though in a few cases individual slides are large enough to be shown on the map.

Other Gravity-Controlled Movements

Due to the fractured nature of most of the area and the steepness of most slopes, very small-scale gravity-controlled downslope movements occur throughout most of the mountains at a high rate. It has been estimated that the average slope angle for the mountains is greater than 65 percent; thus it exceeds in average the angle of repose for unconsolidated rock materials (Krammes, 1963). The extent of this small-scale downslope movement is indicated by widespread sand, rock, or soil cones along the bottoms of stream courses. The rate of downslope movement appears to be accelerated during the summer months, when the upper materials are dry and cohesionless. "Dry creep" or "dry erosion" is the common term applied to this process. Downslope movement by "dry creep" is generally subtle. Much of the time it consists of individual sand grains rolling short distances downslope. Eventually the materials come to temporary rest along stream channels where they form conical piles. The U. S. Forest Service conducted a five-year study of selected sites in the Arroyo Seco and Upper Tujunga drainages in the western San Gabriel Mountains. The study showed that the amount of material moved during the dry season generally exceeds that moved during the wet season (Anderson *et al.*, 1959). This study further showed that south-facing slopes produced more debris than north-facing slopes; thus the amount of debris moved apparently is a function of slope angle and ground cover.

During years of rainfall of normal intensity, much of the material reaching stream channels is not flushed to the valley but only redistributed along the channel. Thus over a period of years a channel can become choked with debris. In periods of extraordinary runoff, the accumulated debris is flushed from the channels to the valley floor. During these infrequent but generally devasting periods of runoff, the debris moved is mostly that which has accumulated in the channel and is not material washed downslope during the runoff.

Fire-Flood Sequence

Brush fires result in greatly accelerated mass-wasting, erosion, and runoff. Accelerated mass-wasting begins during the time of a fire (Krammes, 1960); surficial earth materials normally creeping downslope during the dry season are dried out and rendered cohesionless. Vegetation normally restraining debris on slopes is removed, and the debris "flows" downslope to stream channels. Krammes (1960) found a 4- to 17-fold increase in post-fire debris production compared to pre-fire production.

Brush fires contribute to increased runoff by making the ground generally hydrophobic. Obviously an increase in runoff leads to intensified erosion of side slopes by rilling and sheet overflow and ultimately to scouring of stream channels, which are commonly debris-ladened.

Summer flow of streams also shows an increase for several years following a brush fire. After a 1924 fire in the Fish Canyon drainage, the summer flow was four-fold of normal for several years (Coleman, 1953, p. 4–5). This increase in flow was apparently due to the destruction of stream-bank vegetation.

Coleman (1953, p. 2) gives a well-documented example of how costly and devastating the debris floods are following brush fires in the San Gabriel Mountains. Seven square miles of watersheds above Montrose and La Crescenta were burned in November 1933; on New Year's Day 1934, a severe storm hit the area. Unburned areas nearby produced only the normally high stream flow expected from such a storm, but "the burned area loosed a flood that devastated several towns, brought death to 30 persons, damaged or destroyed 483 homes, and caused $5,000,000 worth of damage." More than 600,000 cubic yards of debris was deposited in the valley as a result of this flood.

Fish Canyon is a striking example of the amount of rock and organic material that can choke canyons and proceed downstream in gigantic debris surges during periods of runoff for many years following brush fires. Along much of the canyon course, trees have been killed by debris filling the canyon to a depth of as much as 10-20 feet locally. The canyon is going through a cycle beginning from degradation prior to a fire, followed by rapid aggradation shortly after the fire, and at present, degradation proceeding down to the pre-fire base level. Exhumed tree trunks, with rock debris clinging to their trunks, in places 18 feet above the stream bed, give evidence of the recent thickness of debris. Individual debris surges, in the lower reaches of the canyons, attained a recorded height of 14 feet in the two winters following the fire.

Today, all larger drainages are controlled by dams; large concrete or earth-fill dams create catchment basins that prevent debris and water from flowing unchecked into the valley areas. To extend the life of some of these catchment basins, concrete crib dams have been constructed upstream. These dams are placed to reduce the interdam stream gradient, thus stabilizing the stream channel and lessening the amount of debris entering the lower catchment basins.

Rate of Degradation of the San Gabriel Mountains

Debris production records of the Los Angeles County Flood Control District present a rare opportunity for the estimation of degradation rates for the general area. The District has data for debris production at 49 catchment basins and flood control dams covering a drainage area of 68.96 square miles on the south flank of the mountains. This drainage area produces an average of 359,219 cubic yards of debris per year or 5,209 cubic yards per square mile per year. This indicates that, during the period of record, the rate of degradation has been .06 inch per year. The same figure is obtained for the mapped area. In the Azusa quadrangle (south half) and the Mt. Wilson quadrangle (east central part), 22.72 square miles of drainage basins are controlled by dams of the District. This area produces an average of 120,073 cubic yards of debris per year, indicating a degradation rate of .06 inch per year. If debris production continued at this rate, 5,000 feet would be eroded in one million years.

A similar figure was obtained by La Marche (U.S. Geological Survey, 1965, p. A175) by a completely different method. Using the exposed root system of a 1,400-year-old pine tree, he calculated an average degradation rate of about 4 acre feet per square mile per year, or .075 inch per year.

These figures indicate extraordinarily rapid degradation; more impressive, though, is the extreme debris production recorded by the Los Angeles County Flood Control District for east Hook basin at the east margin of the map area. This was equivalent to 233,100 cubic yards per square mile, or .8 inch degradation of the drainage basin for the year 1968–69. It has been estimated that the rate of denudation for the entire United States is about 1 foot per 9,000 years. The figure obtained from three of the 49 basins in the San Gabriel Mountains indicates a denudation of 1 foot per 200 years, 45 times the average estimated for the United States: La Marche's data indicate a 54-fold greater rate of denudation.

STRUCTURE

The dominant structural feature of the mapped area is a frontal fault system, generally termed the Sierra Madre fault zone, along which the San Gabriel Mountains have been uplifted. This fault system, largely concealed, may consist in reality of two different, unconnected fault zones, although it forms a single, continuous physiographic break at the front of the San Gabriel Mountains. This break has been inferred to express a continuous fault zone; however, east of Santa Anita Canyon, there are mostly northward-dipping reverse faults that appear to be the continuation of similar faults along the mountain front to the east (Sierra Madre-Cucamonga fault zones—see Rogers, 1967) and of the Raymond Hill fault to the west (see Jennings and Strand, 1967). The Raymond Hill fault, however, extends into the valley area south of Pasadena away from the mountain front. West of Santa Anita Canyon, the visible frontal faults, again termed Sierra Madre fault zone, are nearly vertical. Farther west, what is generally termed the Sierra Madre fault zone enters the San Gabriel Mountains and joins the San Gabriel fault zone in Big Tujunga Canyon. West of La Cañada, in the San Fernando Valley, the frontal fault system is comprised of a series of reverse faults (see Jennings and Strand, 1969).

The relationship between the Duarte Conglomerate and the San Dimas Formation indicates that movements occurred along this zone in late Tertiary times. This conclusion is supported by the angular unconformity between the deformed Duarte Conglomerate and the relatively undeformed overlying San Dimas Formation. Deformation of the unconformity between these two units further demonstrates that movement continued after deposition of the San Dimas Formation. Yerkes *et al.* (1965, p. A51) indicate "movement may have occurred on this zone as early as late middle Miocene time . . . and that the San Gabriel Mountains stood above sea level at the end of the Pliocene (p. A19)."

The major northeast-striking and northward-dipping Clamshell-Sawpit fault zone emerges from the mountains at the mouth of Santa Anita Canyon. This fault zone continues westward, apparently into the valley south of the mountain front. It may be the eastward extension of the reverse faults of the northern San Fernando Valley area. Faults are common to the remaining parts of the area, though many are either too small or too short to be shown on the map.

Sierra Madre Fault Zone East of Santa Anita Canyon

Locally, north of Azusa, the northern part of the Sierra Madre fault zone is clearly exposed. Granitic basement rocks have been thrust over Miocene sedimentary and volcanic rocks. The fault contact, which dips 35 to 70 degrees to the north, is exposed in detail in several artificial cuts. Reverse movement on this fault has produced a large fold in the Tertiary rocks. Bedding adjacent to the fault in the Topanga(?) Formation is overturned to the north and strikes parallel to the fault. Within half a mile south of the fault, bedding is vertical and, farther south, dips steeply to the south.

Several parallel faults of this zone are discontinuously exposed near the eastern edge of the Azusa quadrangle. The wider of these faults have crushed zones as much as several tens of feet wide, and some have gouge zones as much as 4 feet thick. Faults with thin gouge zones are commonly oriented parallel to the larger faults. Volcanic rocks involved in faulting are discolored brick red 2 to 3 feet from the fault.

North of Duarte-Monrovia, the contact between basement rocks and Tertiary rocks is not exposed because much of this area is covered by the San Dimas Formation. Bedding, however, in the Topanga(?) Formation dips northward, a fact that suggests the same relationship exists here between the basement rocks and Tertiary rocks as north of Azusa. No unquestionable overturned bedding was seen, though Shelton's 1955 map shows a number of attitudes of overturned beds in this area. This mapping would indicate the presence of a fold similar to the fold north of Azusa.

Sierra Madre Fault Zone West of Santa Anita Canyon

West of Santa Anita Canyon, the visible frontal faults, in contrast with those to the east, are nearly vertical and some dip steeply southward. These faults are, at best, poorly exposed, though two have very well defined topographic expression for about a mile east of the western edge of the area. The topographic definition of these two faults becomes progressively more vague from west to east between Little Santa Anita Canyon and Santa Anita Canyon. Though small faults are common, no extension of these two apparent major faults was seen on the Chantry Flats road where they should cross the road just west of Santa Anita Canyon.

Light colored mixed granitic and gneissic rock is poorly exposed in several small areas on the south margin of the San Gabriel Mountains west of Santa Anita Canyon; this rock is, in part, in fault contact with quartz diorite. An exposure of this mixed rock in contact with older alluvium is exposed in a cut for a housing development just east of Little Santa Anita Canyon. The older alluvium fills a west-trending "V" in the crystalline rocks. The contact on the south side of the V is a shear; on the north side, the contact is obscure but does not appear to be structural.

Clamshell-Sawpit Fault Zone

Exposed at the mouth of Santa Anita Canyon is a system of parallel and anastomosing northward-dipping faults. This system, which includes the widest individual faults seen in the area, has an over-all width at the mouth of Santa Anita Canyon of more than 3,000 feet. The system was traced northeast to Camp Rincon on the West Fork of San Gabriel River, 10 miles away. The topographic expression of the larger faults of this system is readily apparent. The northeast-trending Clamshell and Sawpit Canyons, for which the zone is named, were originally subsequent valleys developed along the faults. Later erosion resulted in the northward-dipping faults being perched above the bottom of the valleys.

Like the faults of the Sierra Madre system to the east, these are reverse. The northernmost fault, exposed on a cutbank at the mouth of Santa Anita Canyon, dips 35 degrees to the north and with gneiss thrust over unconsolidated gravels. The northernmost mapped fault is the widest of the system, with a crushed and sheared zone as much as 300 feet thick. The extensive gouge of this fault is marked by a line of springs and lush vegetation. This fault is further marked by a series of waterfalls especially pronounced in Clamshell and Monrovia Canyons. Measurements of northward dips on shears within the fault zone range from about 35 to 60 degrees.

Faults south of the largest northern fault are topographically lower and generally only poorly to moderately well exposed. In the area between Santa Anita and Monrovia Canyons, the faults are generally very poorly exposed, except very locally where they have been exposed in artificial cuts. Dips on these faults range from 40 to about 70 degrees north.

The southwesternmost fault exposed has a crushed and sheared zone of about 20 feet; it dips 60 degrees to the north near the mouth of Santa Anita Canyon. To the east, the probable extension of this fault involves locally Duarte-like conglomerate on the footwall and a hanging wall of San Dimas Formation. The cobbles in the Duarte-like conglomerate are mostly 6 to 18 inches in maximum dimension, composed of mainly leucocratic granitic rocks with a few Glendora-like volcanic rock clasts.

Imbrication of the cobbles indicates a dip of about 40 degrees north for the conglomerate, an angle that is parallel to the dip of the fault. Nearby, a parallel fault has a hanging wall with a lens of arkosic and pebbly sandstone between sheared gneiss. The sandstone, which is weathered brick red, contains common small fragments of Glendora-like volcanic rocks.

Structurally, the area between Monrovia and Santa Anita Canyons is very important. It is the junction of

Photo 2. Thrust fault of the Clamshell-Sawpit fault zone at the mouth of Santa Anita Canyon. Gneiss (m_2) is thrust over Quaternary alluvium. See photo 3 for close-up.

the frontal fault zone and the Clamshell-Sawpit fault zone and is the area that includes the projection of the Raymond Hill fault eastward from the vicinity of Pasadena.

Unfortunately, lack of exposures precludes resolving the geometric relationship of these structures. Of the several possibilities, my preferred interpretation is that the Clamshell-Sawpit fault zone becomes the frontal fault zone to the west of Santa Anita Canyon, and is masked by alluvium of the San Gabriel Valley. The steeply dipping faults west of Santa Anita Canyon would be subsidiary to the main fault zone. What is termed the Sierra Madre fault zone east of Santa Anita Canyon leaves the mountain front between Monrovia and Santa Anita Canyons and trends southwest to the Pasadena area, where it is known as the Raymond Hill fault.

This interpretation requires that the Clamshell-Sawpit fault zone extends across Santa Anita Canyon and forms the range-front fault. It is also inferred that this frontal fault system branches to the west. The northernmost of these branches, also generally termed the Sierra Madre fault zone (Jennings and Strand, 1969), enters the mountains and joins the San Gabriel fault zone in Big Tujunga Canyon. The southern branch continues along the mountain front westward into eastern San Fernando Valley. For a similar interpretation, see Dibblee (1968, p. 262).

Faults in the San Gabriel Valley

Ground-water levels and topographic expression have been long used to place faults within the San Gabriel Valley south of the San Gabriel Mountains (Eckis, 1934). Best known of these faults is the Raymond Hill fault, an east-northeast-striking reverse fault. Southwest of the mapped area, in Pasadena, movement along this fault has thrust Topanga Formations rocks over older alluvium (San Dimas(?) Formation), overturning the Topanga Formation on the north side of the fault.

Photo 3. Close-up of thrust pictured in photo 2. Pick at contact for scale.

Farther to the northeast, the fault is marked by a topographic break in the older alluvium (San Dimas(?) Formation); and, locally, ground water is brought to the surface on the north side (upthrown side) of the fault. The topogarphic expression of this fault disappears just west of Santa Anita Canyon wash; the projection of this fault intersects the San Gabriel Mountain front near the mouth of Monrovia Canyon.

A ground-water barrier, termed the Duarte fault, exists just south of and parallel to exposures of Duarte Conglomerate just north of Duarte. This barrier, apparently extending both east and west between Santa Anita Canyon and Azusa, is interpreted as a buried fault in the area of Duarte. This fault possibly represents the southern fault of the Sierra Madre fault zone.

Magnitude and Recency of Fault Displacement

The abruptly rising front of the San Gabriel Mountains suggests that there has been considerable reverse dip-slip movement on the frontal fault system. Between Azusa and Duarte, two exploratory wells drilled about a mile and a half south of exposed granitic rock bottomed at depths of 6,914 feet and 7,854 feet in middle Miocene Glendora Volcanics and Topanga Formation respectively (California Division of Oil and Gas, 1962, 1969). Basement rocks of the San Gabriel Mountains rise abruptly 3,000 feet above the valley floor, suggesting that the total vertical displacement here is on the order of 10,000 feet.

In the Clamshell-Sawpit fault zone, the thrusting of gneiss over older alluvium at the mouth of Santa Anita Canyon and the height of the mountain front suggest vertical displacement of about 4,000 feet. Just southwest of the mapped area, basement on the Raymond Hill fault is probably offset the same order of magnitude.

In the mapped area, evidence is lacking for the horizontal component of movement. Clasts in the Topanga Formation and Duarte Conglomerate include rocks of widespread distribution in the San Gabriel

Mountains. Yerkes and Campbell (1971) consider the horizontal component of movement to be over 50 miles in a left-lateral sense. They further consider this movement to have been initiated in mid-Miocene time in response to sea-floor spreading (Campbell and Yerkes, 1971).

Regional geologic considerations indicate an active seismic state for the frontal fault system of the San Gabriel Mountains; however, prior to the 1971 San Fernando earthquake, there had been little historic seismic activity. In the mapped area, the youngest documented fault displacement is post-San Dimas Formation and post-older stream deposits (Qao_1) and pre-younger alluvium (Qal); however, more recent movements are likely, based upon the tectonic setting. The lack of surface expression of recent movements does not preclude such movements, as low scarps in alluvium are readily destroyed and vanish quickly. Such pronounced physiographic breaks as Bradbury Mesa may indeed be modified fault scarps.

Regionally, the most obvious indication of seismic activity was the February 9, 1971, San Fernando earthquake, which produced multiple surface fault breaks (Kahle *et al.*, 1971; Kamb *et al.*, 1971; and U.S. Geological Survey Staff, 1971). Regionally the recency of ground rupture along the frontal fault system is indicated by such fault scarps as those that cut alluvium (alluvial fan of Day Canyon) near Cucamonga (Eckis, 1928; Morton, unpublished mapping 1971) and the Raymond Hill fault scarp immediately west of the area (Eckis, 1934). Proctor *et al.* (1970, p. 8) reports 11 occurrences of basement rocks thrust over Quaternary alluvial deposits along a 22-mile segment of the frontal fault system west of Glendora.

SEISMICITY

There is no record of epicenters of moderate or large earthquakes in the mapped area, and only a few are recorded to the east and west along the mountain front. However, considering geologic evidence for recency of fault movements, the frontal fault system (including Clamshell-Sawpit fault zone) must be considered active and capable of producing earthquakes comparable to the 1971 San Fernando earthquake. Fault movement most likely will be of the reverse dip-slip (thrust) type that occurred in the San Fernando earthquake. The steepness of the terrain and highly fractured nature of the basement rocks in the San Gabriel Mountains will result in widespread landsliding (Morton, 1971a, b). The intensity and distribution of landsliding will be commensurate with the magnitude and location of an earthquake. Future construction should consider this seismic potential of the area.

Data obtained after the San Fernando earthquake, including the nature and distribution of surface ruptures, the obscure nature of pre-existing reactivated faults in valley alluvium, and the potential in valley areas for low gradient (gentle slope) landslides (see Youd, 1971), deserve particular attention in construction planning. Sites for critical structures in the valley areas should be examined for indications of obscured recent faulting, and both valley and hillside development should take into consideration secondary earthquake effects such as landsliding.

REFERENCES

Anderson, H. W., Coleman, G. B., and Zinke, P. J., 1959, Summer slide and winter scour... dry wet erosion in southern California: U.S. Forest Service, Pacific Southwest Forest and Ranger Experiment Station, Tech. Paper #36, 12 p.

Bailey, T. H., and Jahns, R. H., 1954, Geology of the Transverse Range province, southern California *in* R. H. Jahns ed., Geology of Southern California: California Div. Mines Bull. 170, Chap. ii, cont. 6, p. 83–106.

California Division of Oil and Gas, 1962, Summary of operations of California oil fields, 256 p.

California Division of Oil and Gas, 1969, Summary of operations of California oil fields, 132 p.

Campbell, R. H., and Yerkes, R. F., 1971, Cenozoic evolution of the Santa Monica Mountains—Los Angeles basin area: II. Relation to plate tectonics of the northeast Pacific Ocean: Geol. Soc. America Cordilleran Sect. Meeting, Riverside, California, p. 92.

Coleman, E. A., 1953, Fire and water in southern California's mountains: U.S. Forest Service, California Forest and Ranger Experiment Station, Misc. Paper #3, 8 p.

Dibblee, T. W., Jr., 1968, Displacements on the San Andreas fault system in the San Gabriel, San Bernardino, and San Jacinto mountains, southern California *in* Dickenson, W. R., and Grantz, A., ed., Proceedings of conference on geologic problems of San Andreas fault system: Stanford Univ. Pub. in Geol. Sci, v. XI, p. 260–276.

Eckis, Rollin, 1928, Alluvial fans of the Cucamonga district, southern California: Jour. Geology, v. 36, p. 224–247.

Eckis, Rollin, 1934, Geology and groundwater storage capacity of valley fill: California Div. Water Resources Bull. 45, p. 279.

Ehlig, P. L., 1966, Displacement along the San Gabriel fault, San Gabriel Mountains, southern California: Geol. Soc. Amer. Program, 1966 Annual Meeting, p. 60, (abstract).

Hill, M. L., 1930, Structure of the San Gabriel Mountains, north of Los Angeles, California: Univ. California Pub., Bull. Dept. Geol. Sci., v. 19, p. 137–170.

Jennings, C. W., and Strand, R. G., 1969, Geologic map of California, Olaf P. Jenkins, ed., Los Angeles sheet: California Div. Mines and Geology.

Kahle, J. E., Barrows, A. G., Weber, F. H., Jr., and Saul, R. B., 1971, Geologic surface effects of the San Fernando earthquake: California Geology, v. 24, no. 4–5, p. 75–79.

Kamb, Barclay, Silver, L. T., Abrams, M. J., Carter, B. A., Jordan, T. H., and Minster, J. B., 1971, Pattern of faulting and nature of fault movement in the San Fernando earthquake *in* The San Fernando, California earthquake of February 9, 1971: U.S. Geol. Survey Prof. Paper 733, p. 41–54.

Krammes, J. S., 1960, Erosion from mountain side slopes after fire in southern California: U.S. Forest Service Research note #171, 8 p.

Krammes, J. S., 1963, Seasonal debris movement from steep mountainside slopes in southern California: U.S. Forest Service, Pacific Southwest Forest and Ranger Experiment Station, Preliminary draft of paper submitted to the Federal Inter-Agency Conf. of Sedimentation, Jackson, Mississippi, January 28–February 1, 1963, p. 11.

Larsen, E. S., Jr., Gottfried, David, Jaffe, H. W., and Waring, C. L., 1958, Lead-alpha ages of the Mesozoic batholiths of western North America: U.S. Geol. Survey Bull. 1070-B, 62 p.

Miller, W. J., 1934, Geology of the western San Gabriel Mountains of California: Pub. Univ. California, Los Angeles in Math. and Physical Sci., v. I, no. 1, 114 p.

Morton, D. M., 1971a, Seismically triggered landslides above San Fernando Valley: California Geology, v. 24, no. 4–5, p. 80–82.

Morton, D. M., 1971b, Seismically triggered landslides in the area above the San Fernando Valley *in* The San Fernando, California earthquake of February 9, 1971: U.S. Geol. Survey Prof. Paper 733, p. 99–104.

Proctor, R. J., Payne, C. M., and Kalin, D. C., 1970, Crossing the Sierra Madre fault zone in the Glendora tunnel, San Gabriel Mountains, California: Engineering Geology (Elsevier), v. 4, p. 5–63.

Rogers, T. H., 1967, Geologic map of California, Olaf P. Jenkins, ed., San Bernardino sheet: California Div. Mines and Geology.

Shelton, J. S., 1946, Geology of northeast margin of San Gabriel basin, Los Angeles County, California: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 63.

Shelton, J. S., 1955, Glendora volcanic rocks, Los Angeles basin, California: Geol. Soc. Amer. Bull., v. 66, p. 45–90.

Silver, L. T., 1966, Preliminary history for the crystalline complex of the central Transverse Ranges, Los Angeles County, California: Geol. Soc. America Program, 1966 Annual Meeting, p. 201–202.

U.S. Geological Survey, 1965, Geological Survey Research 1965, Chapter A: U.S. Geol. Survey Prof. Paper 525A, 376 p.

U.S. Geological Survey Staff, 1971, Surface faulting *in* The San Fernando California earthquake of February 9, 1971: U.S. Geol. Survey Prof. Paper 733, p. 55–76.

Yerkes, R. F., and Campbell, R. H., 1971, Cenozoic evolution of the Santa Monica Mountains—Los Angeles basin area: I. Constraint on tectonic models: Geol. Soc. America Abstract Cordilleran Meeting, Riverside, California, p. 222.

Yerkes, R. F., McCulloh, T. H., Schoellhamer, J. E., and Vedder, J. G., 1965, Geology of the Los Angeles basin, California—an introduction: U.S. Geol. Survey Prof. Paper 420-A, 57 p.

Youd, T. L., 1971, Landsliding in the vicinity of the Van Norman Lakes *in* The San Fernando, California earthquake of February 9, 1971; U.S. Geol. Survey Prof. Paper 733, 254 p.

Young, L. E., and Croff, R. W., 1967, Magnitude and frequency of floods in the United States: U.S. Geol. Survey Water Supply Paper 1685, v. I, pt. II, 272 p.

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CALIFORNIA DIVISION OF MINES AND GEOLOGY
WESLEY G. BRUER, STATE GEOLOGIST

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF CONSERVATION

PREPARED IN COOPERATION WITH THE COUNTY OF LOS ANGELES
DEPARTMENT OF COUNTY ENGINEER
AND THE LOS ANGELES COUNTY FLOOD CONTROL DISTRICT

EAST CENTRAL PART MT. WILSON QUADRANGLE
SPECIAL REPORT 105 PLATE 1

EXPLANATION

CENOZOIC — QUATERNARY — Holocene

Qaf

Artificial fill

Fill which is compacted and/or uncompacted and is mainly locally obtained; shown only for major road, levee, and housing development fill; includes waste from quarry and tunnel excavations. Designated Qaf_1 in areas of cut-and-fill, and "cut" and/or Qaf_2 in areas that are primarily excavated.

Qal

Alluvium

Qc

Colluvial debris

Includes, on ridge tops, decomposed rock which in large part may be in situ.

Qls

Landslide debris

Landslides that appear to have resulted from primarily slump-type failure (rotational) and that possess relatively well-defined scarp areas and slump block(s) are designated Qls_1. Scarp areas and flattened surface(s) on the tops of slump block(s) are outlined where possible. Deposits of inferred landslide origin are queried.

Pleistocene ?

Qsd

San Dimas Formation

Qao_2

Older alluvial deposits

Qao_1

Older stream deposits

Where two adjacent terrace deposits are of different ages, the older (topographically higher) deposit is designated Qao_{1a}; the younger is designated Qao_{1b}.

TERTIARY — Miocene

Td_2

Leucocratic hypabyssal dikes

Td_1

Hypabyssal dikes basic to intermediate in composition

MESOZOIC — CRETACEOUS?

qd

Quartz diorite

Mostly quartz diorite; grades into granodiorite, quartz monzonite, and diorite. Rock consisting of a mixture of quartz diorite and metamorphic rock is designated [symbol]. The mixture of quartz diorite and abundant fragments of m_4 in upper Santa Anita Canyon is designated qd_2.

PALEOZOIC — UPPER PALEOZOIC

m_{4a} / m_{4b}

Hornblende Orthogneiss

Where it is essentially uniform, the rock is designated m_{4a}. Heterogeneous mixture of this gneiss and gneissic granitic rock is designated m_{4b}.

PRECAMBRIAN? TO CRETACEOUS?

m_3

Undivided biotite gneiss and gneissic granitic rock

m_2

Undivided biotite and hornblende gneiss, calc-silicate marble, and amphibolite;

Qal + Qaf | $Qc + Qao_1$

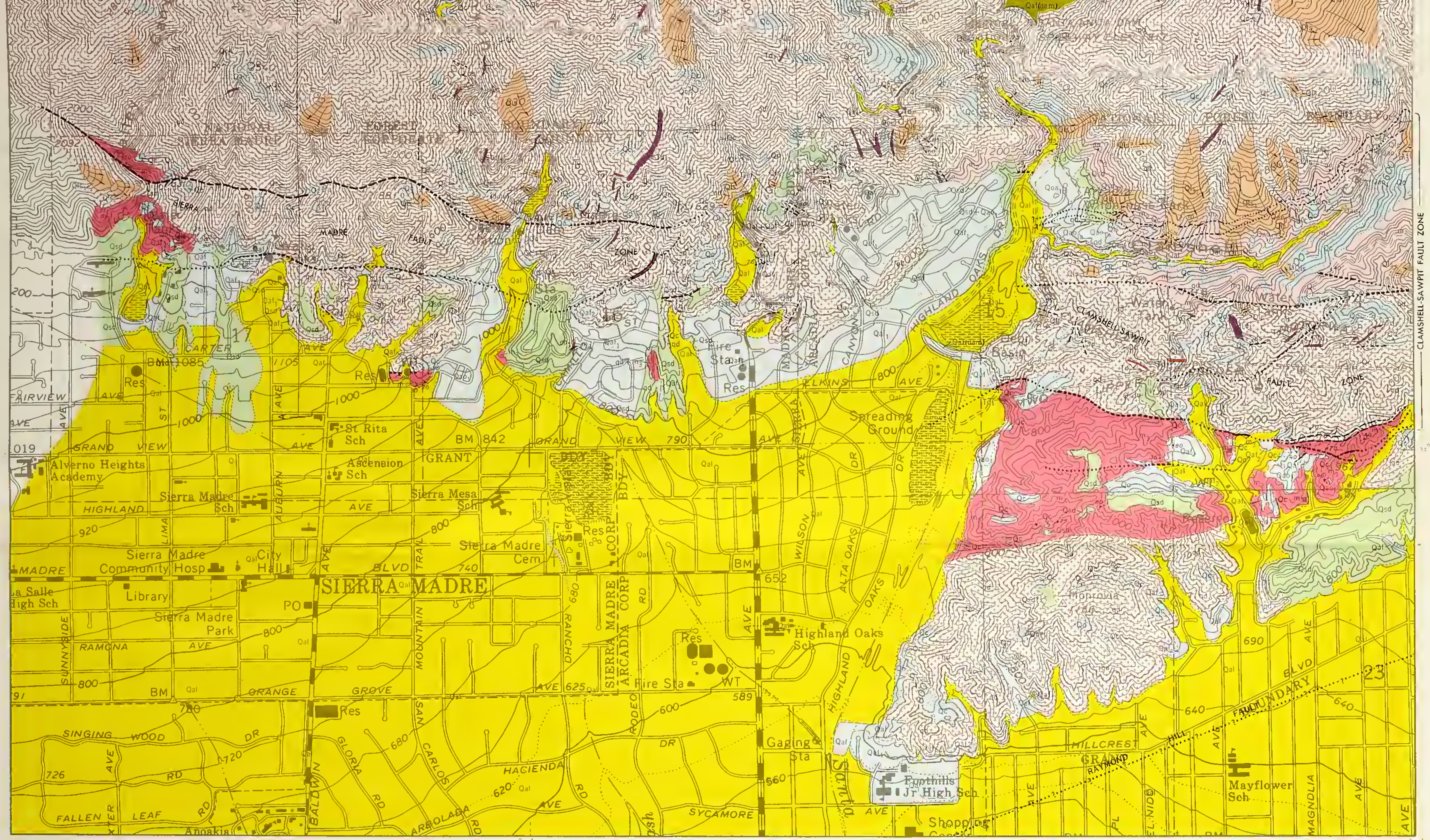
Qc + Qsd | $Qsd + Qao_1$

$qd + m_3$ | $qd + m_{4a}$

Combined geologic units

SYMBOLS

Contact showing dip

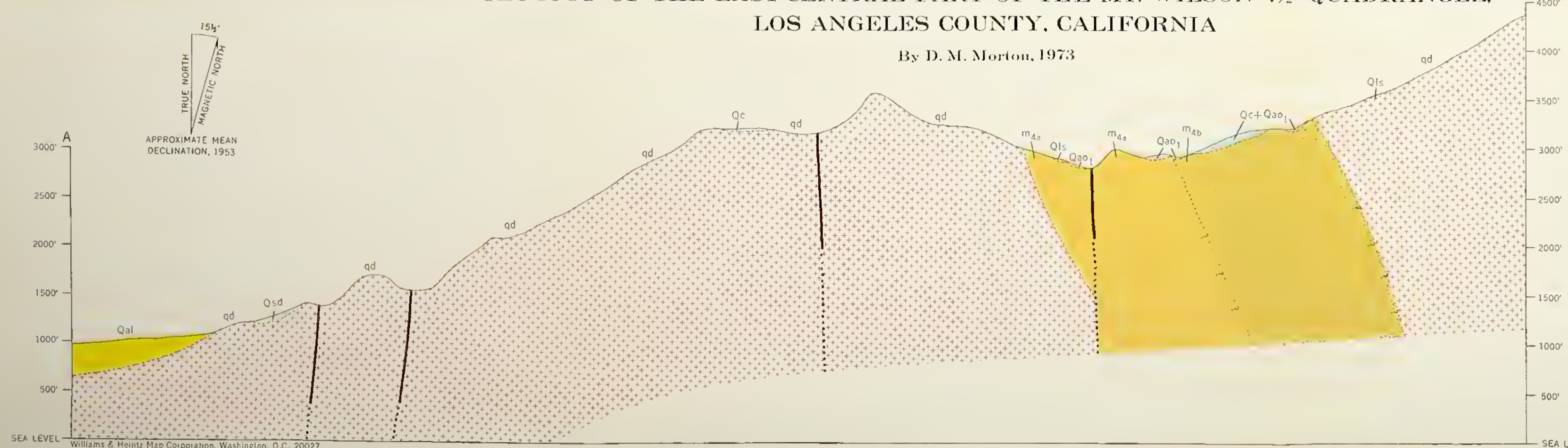


TOPOGRAPHIC BASE BY USGS
This map is an enlargement of a 1:24 000-scale published map

GEOLOGY MAPPED BY D. M. MORTON 1962-67
CARTOGRAPHY DRAFTED BY J. OWEN TAMBERT

GEOLOGY OF THE EAST-CENTRAL PART OF THE MT. WILSON 7½′ QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

By D. M. Morton, 1973



Williams & Heintz Map Corporation, Washington, D.C. 20027

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

PALEOZOIC | UPPER PALEOZOIC
PRECAMBRIAN ? TO CRETACEOUS ?

Hornblende Orthogneiss
Where it is essentially uniform, the rock is designated m_{4a}. Heterogeneous mixture of this gneiss and gneissic granitic rock is designated m_{4b}.

Undivided biotite gneiss and gneissic granitic rock (m_3)

Undivided biotite and hornblende gneiss, calc-silicate marble, and amphibolite (m_2)

Qal + Qaf; Qc + Qao_1; Qc + Qsd; Qsd + Qao_1; qd + m_3; qd + m_{4a}

Combined geologic units

SYMBOLS

Contact showing dip
(solid where accurately located; long dashed where approximately located; short dashed where indefinite or alluvial contact; dotted where concealed or gradational; queried where inferred)

Fault showing dip
(double line where fracture zone of fault is wide enough to have mappable bounds; attitude symbol within fault zone indicates orientation of planar shear surface that appears to parallel the fault plane. Single heavy line where major fault plane or zone appears to be too narrow to show mappable bounds; light line where minor faults appear. Solid where accurately located; long dashed where approximately located; short dashed where indefinite; dotted where concealed; queried where inferred.)

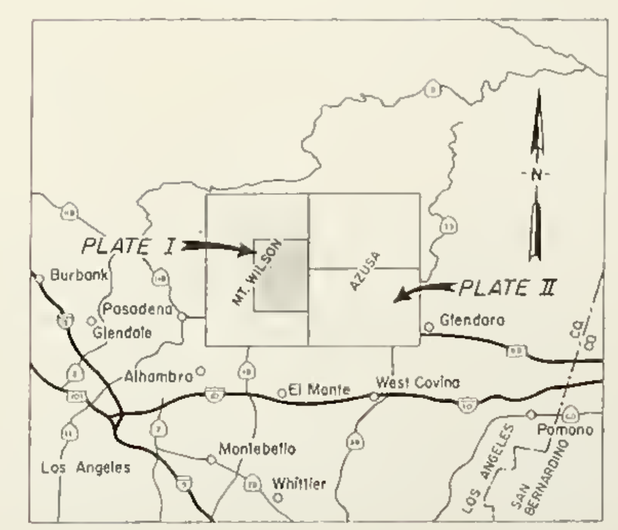
Note: *(Where fault plane is exposed in cliff face overlain by terrace deposits and the fault symbol extends into terrace materials or into alluvium, it is meant only to show fault attitude as seen in cliff face and does not imply that the fault cuts either terrace deposits or alluvium)*

PLANAR FEATURES

Strike and dip of foliation in metamorphic and igneous (plutonic) rocks. Includes some layering (schlieren) in igneous rocks

Vertical foliation

Strike and dip of joint in igneous rocks

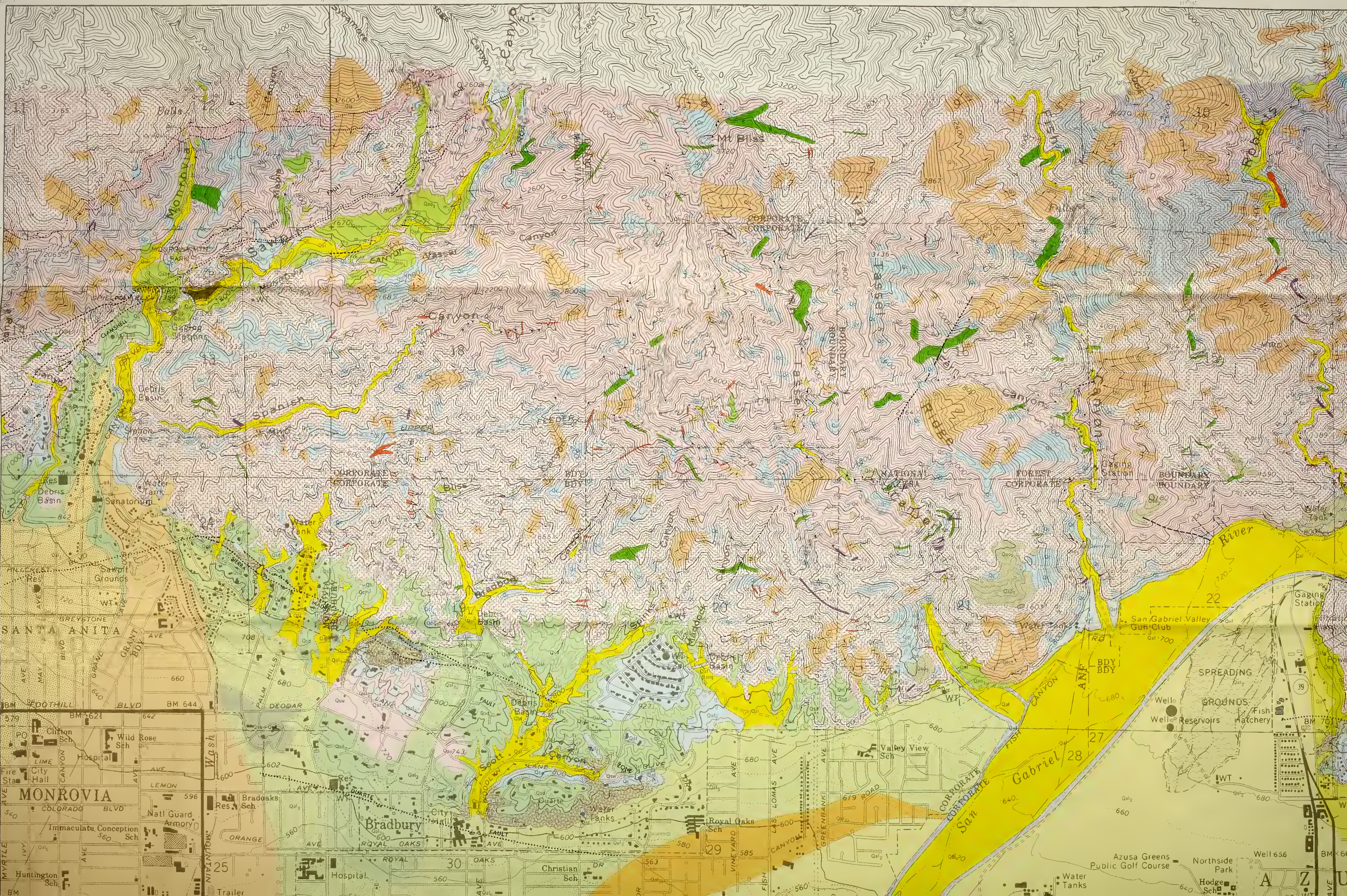


INDEX MAP SHOWING EAST CENTRAL PART MT. WILSON QUADRANGLE

CALIFORNIA DIVISION OF MINES AND GEOLOGY
WESLEY G. BRUER, STATE GEOLOGIST

STATE OF CALIFORNIA
THE RESOURCES AGENCY
DEPARTMENT OF CONSERVATION

PREPARED IN COOPERATION WITH THE COUNTY OF LOS ANGELES
DEPARTMENT OF COUNTY ENGINEER
AND THE LOS ANGELES COUNTY FLOOD CONTROL DISTRICT



DEPARTMENT OF COUNTY ENGINEER
AND THE LOS ANGELES COUNTY FLOOD CONTROL DISTRICT

SOUTH HALF AZUSA QUADRANGLE
SPECIAL REPORT 105 PLATE 2

EXPLANATION

CENOZOIC — QUATERNARY — Holocene

Qaf
Artificial fill
Fill which is compacted and/or uncompacted and is mainly locally obtained; shown only for major road, levee, and housing development fill; includes waste from quarry and tunnel excavations. Designated Qaf_1 in areas of cut-and-fill, and "cut" and/or Qaf_2 in areas that are primarily excavated.

Qal
Alluvium
Alluvium including: (1) Unconsolidated, generally grayish alluvium on canyon floors within the mountains. (2) San Gabriel River channel alluvium. (3) Undifferentiated alluvium of the San Gabriel Valley in the Mount Wilson quadrangle.

Qal_5
Relatively younger alluvium of Monrovia-Sawpit Canyons fan

Qal_4
Relatively older alluvium of Monrovia-Sawpit Canyons fan

Qal_{3a}
Alluvium of Bradbury Canyon fan

Qal_3
Alluvium west of San Gabriel Canyon fan

Qal_{2a}
Alluvium transitional between Qal_2 and Qal_3

Qal_2
Alluvium of the San Gabriel River fan

Qal_1
Alluvium east of San Gabriel fan

Qta
Talus

Qac
Alluvial cone

Qc
Colluvial debris
Includes, on ridge tops, decomposed rock which in large part may be in situ.

Qsw
Slope wash

Qls
Landslide debris
Landslides that appear to have resulted from primarily slump-type failure (rotational) and that possess relatively well defined scarp areas and slump block(s) are designated Qls_1. Scarp areas and flattened surface(s) on the tops of slump block(s) are outlined where possible. Landslides of primarily planar-type failure and thicker than 5 feet are designated Qls_2; similar but thinner landslides are designated Qls_3. Landslide deposits formed essentially by rockfall accumulations of angular rock fragments and blocks on or at the bases of steep slopes are designated Qls_4. Deposits of inferred landslide origin are queried.

Pleistocene?

Qsd
San Dimas Formation

Qao_2
Older alluvial deposits

Qao_1
Older stream deposits
Where two adjacent terrace deposits are of different ages, the older (topographically higher) deposit is designated Qao_{1a}; the younger is designated Qao_{1b}.

TERTIARY — Pliocene?

Tdc
Duarte Conglomerate

Miocene

Tt
Topanga(?) Formation

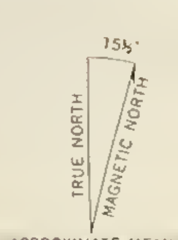
Tg
Glendora Volcanics
Andesitic dikes designated Tgi, questionable flows designated Tgf, and basalt flows designated Tgb.

Td_2
Leucocratic hypabyssal dikes

Td_1

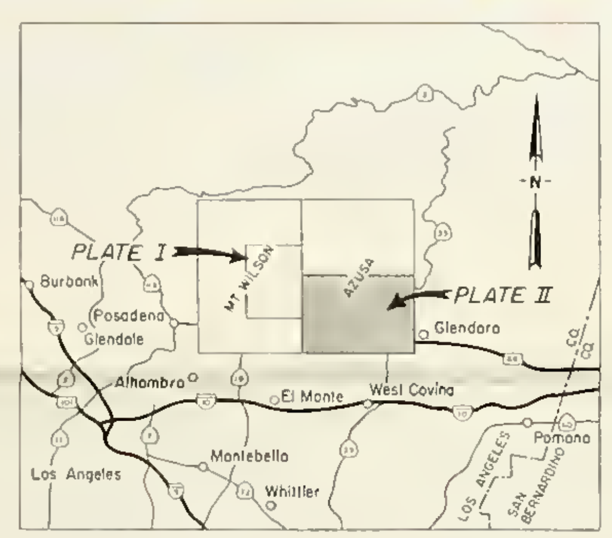
TOPOGRAPHIC BASE BY USGS
This map is an enlargement of a 1:24 000-scale published map

R 11 W R 10 W



APPROXIMATE MEAN DECLINATION, 1953

QUADRANGLE LOCATION

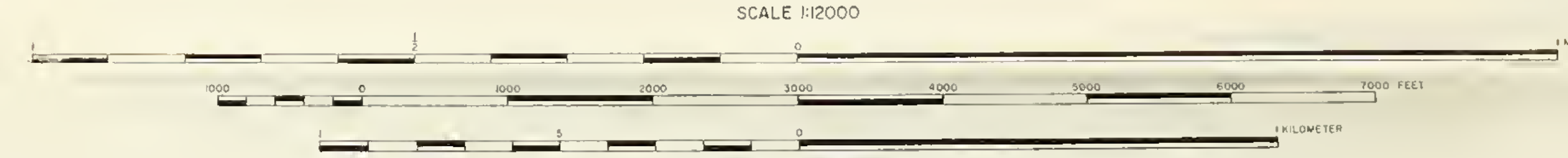


INDEX MAP SHOWING SOUTH HALF OF THE AZUSA QUADRANGLE

GEOLOGY OF THE SOUTH HALF OF THE AZUSA 7½′ QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

By D. M. Morton, 1973

SCALE 1:12000

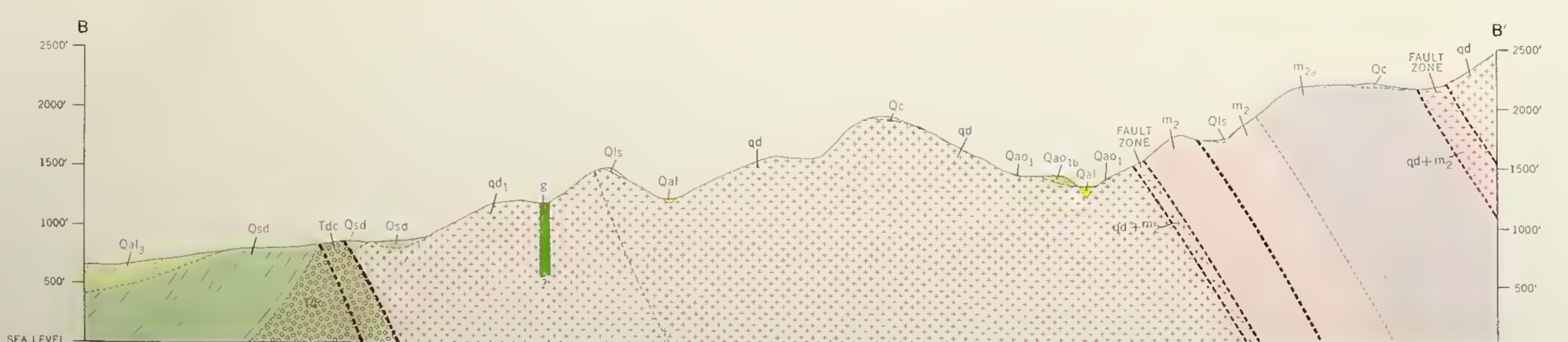


CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

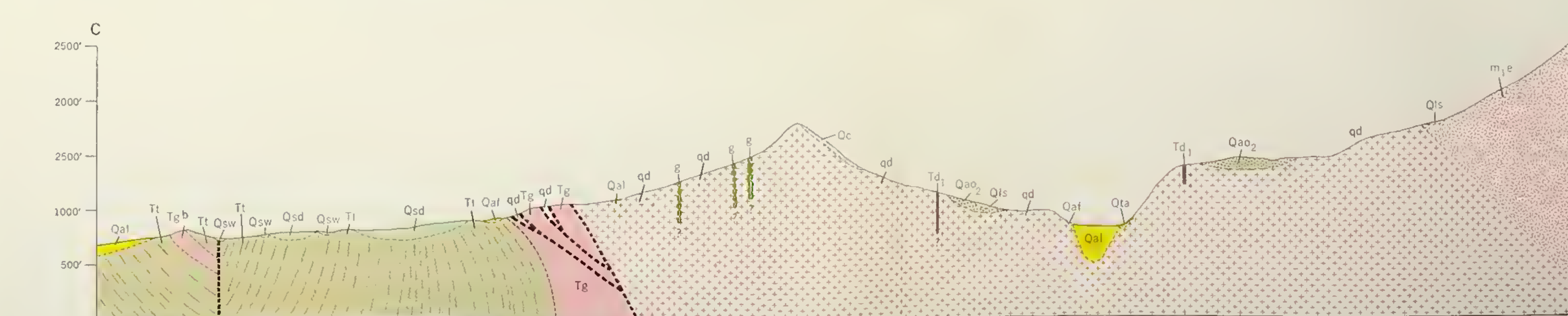
Contact showing dip
(solid where accurately located; long dashed where a… dashed where indefinite or alluvial contact; dotted wh… queried where inferred)

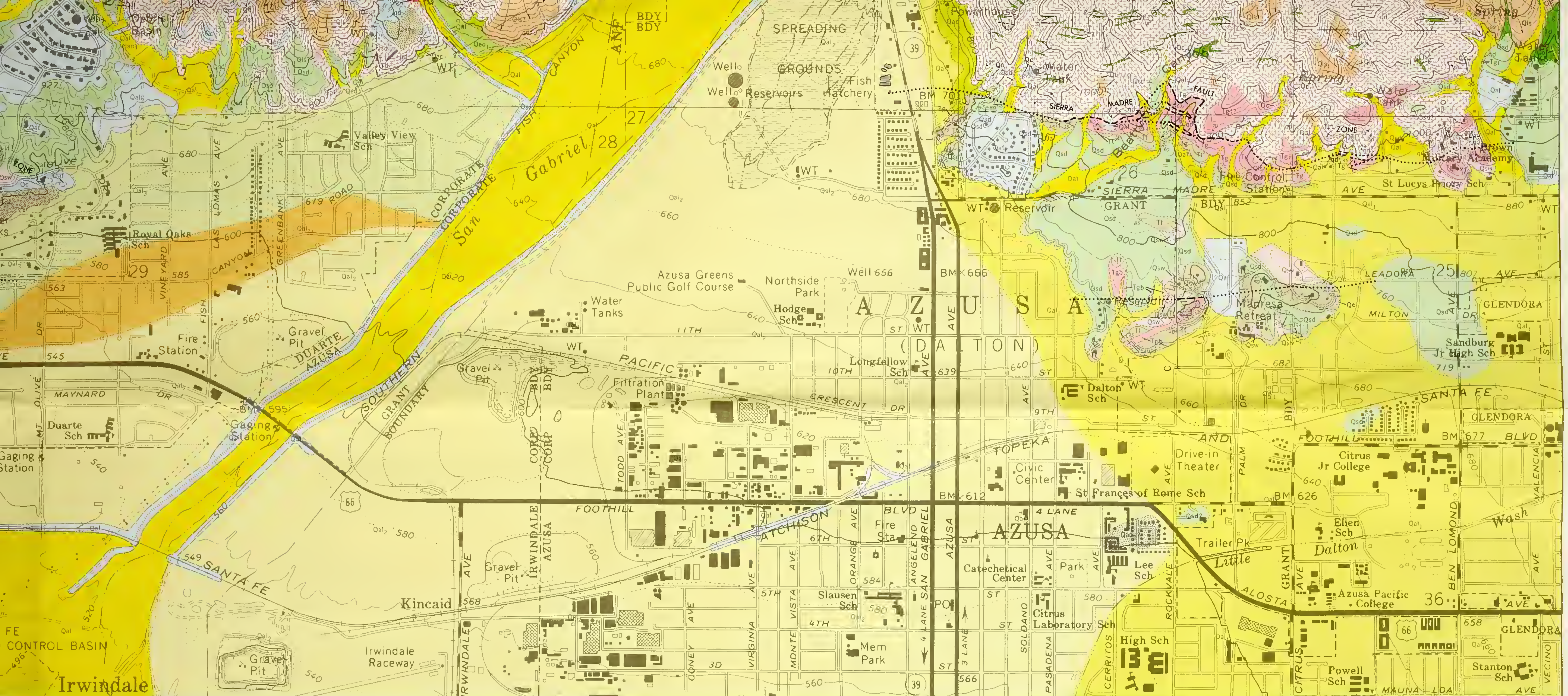
Fault showing dip
(double line where fracture zone of fault is wide enou… attitude symbol within fault zone indicates orienta… that appears to parallel the fault plane. Single heavy… or zone appears to be too narrow to show mappable b… faults appear. Solid where accurately located; long… located; short dashed where indefinite; dotted where con…

Note: *(Where fault plane is exposed in cliff face ove… the fault symbol extends into terrace materials or int… to show fault attitude as seen in cliff face and does n… either terrace deposits or alluvium)*



Williams & Heintz Map Corporation, Washington, D.C. 20027





GEOLOGY OF THE SOUTH HALF OF THE AZUSA 7½′ QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

By D. M. Morton, 1973

SCALE 1:12000

1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0 1 KILOMETER

CONTOUR INTERVAL 40 FEET
DOTTED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

Contact showing dip
(solid where accurately located; long dashed where approximately located; short dashed where indefinite or alluvial contact; dotted where concealed or gradational; queried where inferred)

Fault showing dip
(double line where fracture zone of fault is wide enough to have mappable bounds; attitude symbol within fault zone indicates orientation of planar shear surface that appears to parallel the fault plane. Single heavy line where major fault plane or zone appears to be too narrow to show mappable bounds; light line where minor faults appear. Solid where accurately located; long dashed where approximately located; short dashed where indefinite; dotted where concealed; queried where inferred.)

Note: *(Where fault plane is exposed in cliff face overlain by terrace deposits and the fault symbol extends into terrace materials or into alluvium, it is meant only to show fault attitude as seen in cliff face and does not imply that the fault cuts either terrace deposits or alluvium)*

SYMBOLS

PLANAR FEATURES

Strike and dip of bedding

Vertical beds

Strike and dip of overturned beds;
(top of beds determined from sedimentary structures)

Strike and dip of foliation in metamorphic and igneous (plutonic) rocks. Includes some layering (schlieren) in igneous rocks

Vertical foliation

Strike and dip of joint in igneous rocks

LINEAR FEATURES
(May be used in combination with Planar Features symbols)

Lineation showing bearing and plunge

Horizontal lineation

Minor fold, showing bearing and plunge of axis

Deposits of inferred landslide origin are queried.

Pleistocene?

Qsd — San Dimas Formation

Qao₂ — Older alluvial deposits

Qao₁ — Older stream deposits
Where two adjacent terrace deposits are of different ages, the older (topographically higher) deposit is designated Qao_{1a}; the younger is designated Qao_{1b}.

Pliocene?

Tdc — Duarte Conglomerate

Miocene — TERTIARY

Tt — Topanga(?) Formation

Tg — Glendora Volcanics
Andesitic dikes designated Tgi, questionable flows designated Tgf, and basalt flows designated Tgb.

Td_2 — Leucocratic hypabyssal dikes

Td_1 — Hypabyssal dikes basic to intermediate in composition

MESOZOIC — CRETACEOUS?

g — Leucogranitic rocks

qd — Quartz diorite
Mostly quartz diorite; grades into granodiorite, quartz monzonite, and diorite. Rock consisting of a mixture of quartz diorite and metamorphic rock is designated [illegible]; where the rock is primarily of diorite composition, it is designated [illegible]. Mixture of quartz diorite, leucocratic granitic rock, and light-colored gneiss east of Monrovia Canyon is designated qd_1.

CRETACEOUS OR OLDER

m_2 / m_{2a} — Undivided biotite and hornblende gneiss, calc-silicate marble, and amphibolite;
gneiss cut by abundant leucogranitic rock designated m_{2a}.

m_1f — Gneissic quartz monzonitic rock

m_1e — Mixed biotite and/or hornblende gneiss where well layered designated ss

m_1d — Cataclastic rock

m_1c — Biotite gneiss

m_1b — Mixed gneissic quartz diorite and gneiss

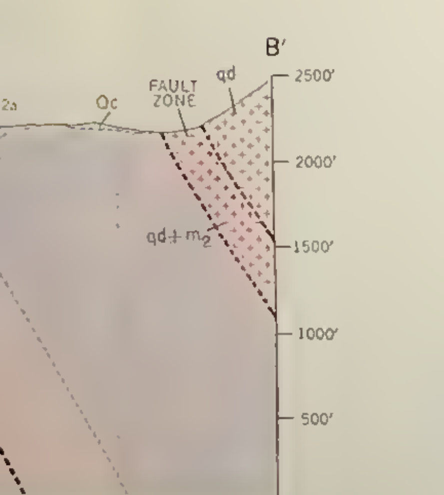
m_1a — Hornblende gneiss

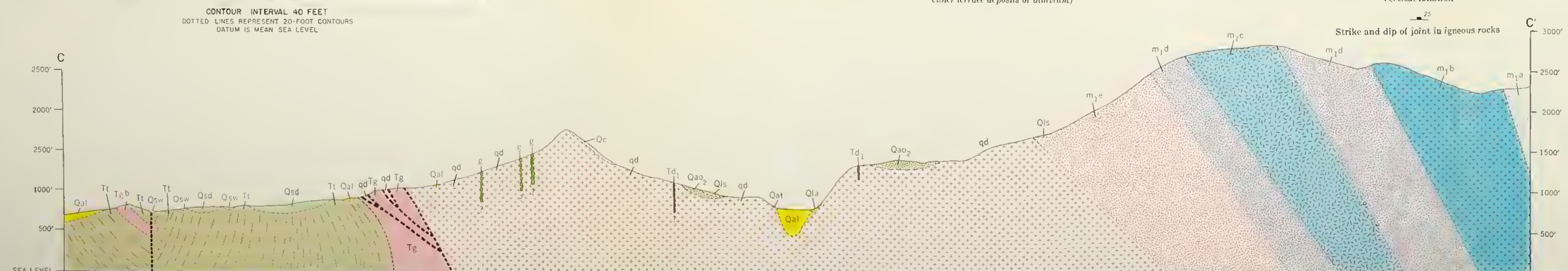
Qc + Qsw | Qc + Qsd

Qc + Qal | Qsw + Qsd

Qc + Qao₁ | qd + m₁

Combined geologic units





Qc
Qsd
Qls
Td₁
Qal
qd
Qaf(dam)
Water Tank
Qls₁
1600
70
20
40
25